JANUARY 1954

Journal

VOL. 46 • NO. 1

AMERICAN WATER WORKS ASSOCIATION

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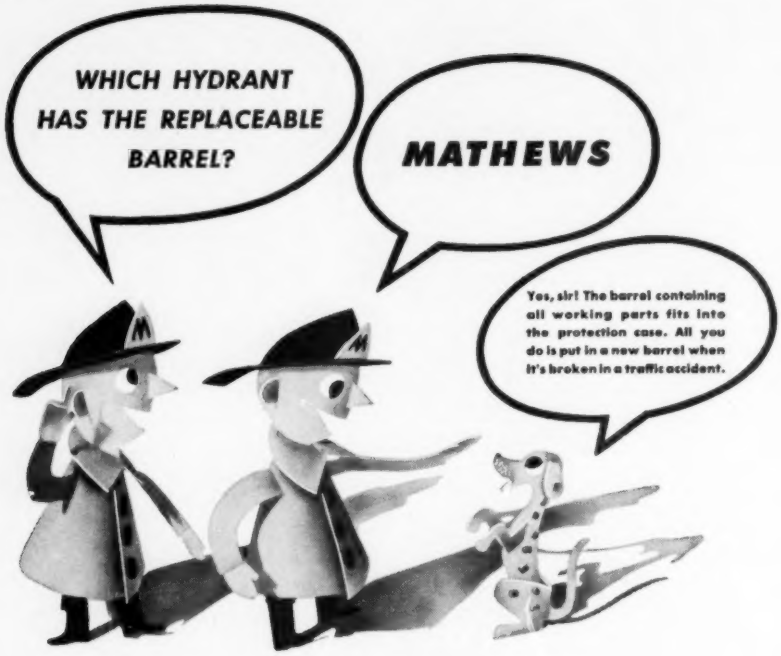
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Journal

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January 1954

Vol. 46 • No. 1

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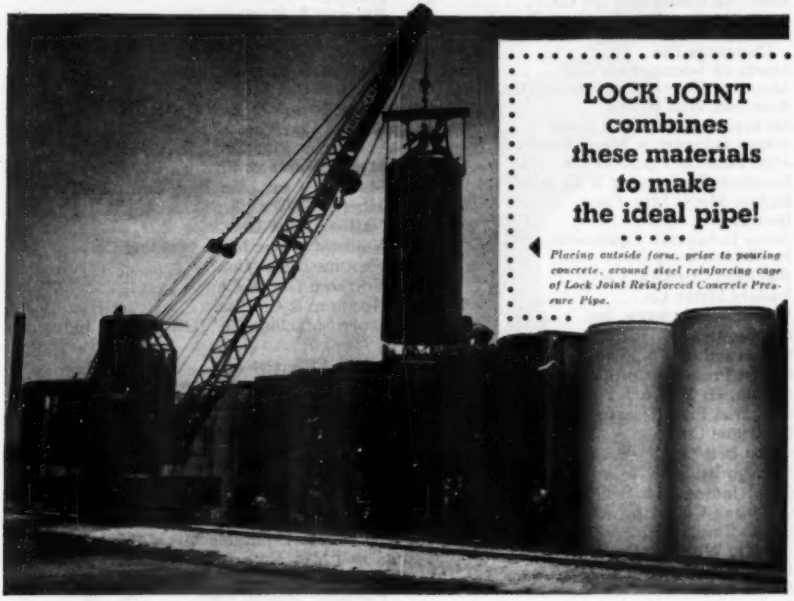

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AWWA SECTIONS

Jan. 19, 1954—New York Section Winter Luncheon Meeting, at Commodore Hotel, New York. Secretary, Kimball Blanchard, Rm. 1922, 50 W. 50 St., New York 20, N.Y.

Feb. 10–12—Indiana Section at Lincoln Hotel, Indianapolis. Secretary, G. G. Fassnacht, State Dept. of Health, 1330 W. Michigan St., Indianapolis 7, Ind.

Feb. 16—New Jersey Section Winter Luncheon Meeting, at Essex House, Newark, N.J. Secretary, C. B. Tygert, Box 178, Newark 1, N.J.

Mar. 17–19—Illinois Section at LaSalle Hotel, Chicago. Secretary, Dewey W. Johnson, Research Engr., Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago 3, Ill.

Mar. 18—New England Section at Hotel Statler, Boston. Secretary, George G. Bogren, Partner, Weston & Sampson, 14 Beacon St., Boston 8, Mass.

Mar. 29–31—Southeastern Section at Poinsette Hotel, Greenville, S.C. Secretary, N. M. deJarnette, 245 State Office Bldg., Atlanta 3, Ga.

Apr. 7–9—Kansas Section at Broadview Hotel, Emporia. Secretary, Harry W. Badley, Repr., Neptune Meter Co., 119 W. Cloud, Salina, Kan.

Apr. 12–14—Canadian Section at Royal York Hotel, Toronto. Secretary, A. E. Berry, Director, Ontario Dept. of Health, Parliament Bldgs., Toronto 8, Ont.

Apr. 22–23—Nebraska Section at Cornhusker Hotel, Lincoln. Secretary, E. Bruce Meier, Asst. Prof. of Civil Engineering, Univ. of Nebraska, Lincoln, Neb.

Apr. 22–23—New York Section at Woodruff Hotel, Watertown. Secretary, Kimball Blanchard, Rm. 1922, 50 W. 50 St., New York 20, N.Y.

AWWA ANNUAL CONFERENCE

Seattle, Wash. **May 23-28, 1954**

All reservations will be cleared through the AWWA office. The hotels have agreed to accept no reservations for the 1954 Conference except as they are requested on the standard form, through the AWWA.

(Continued on page 76)

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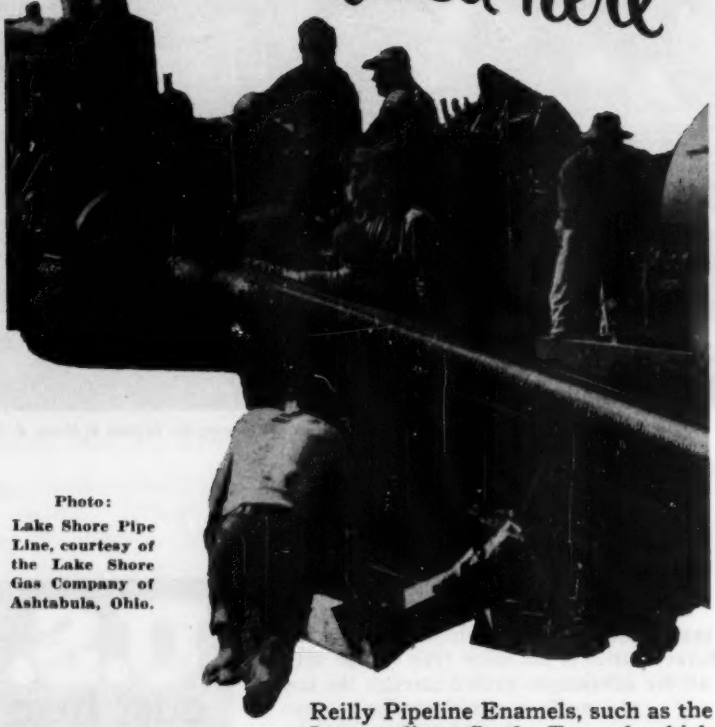

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Lake Shore Pipe Line, courtesy of the Lake Shore Gas Company of Ashtabula, Ohio.

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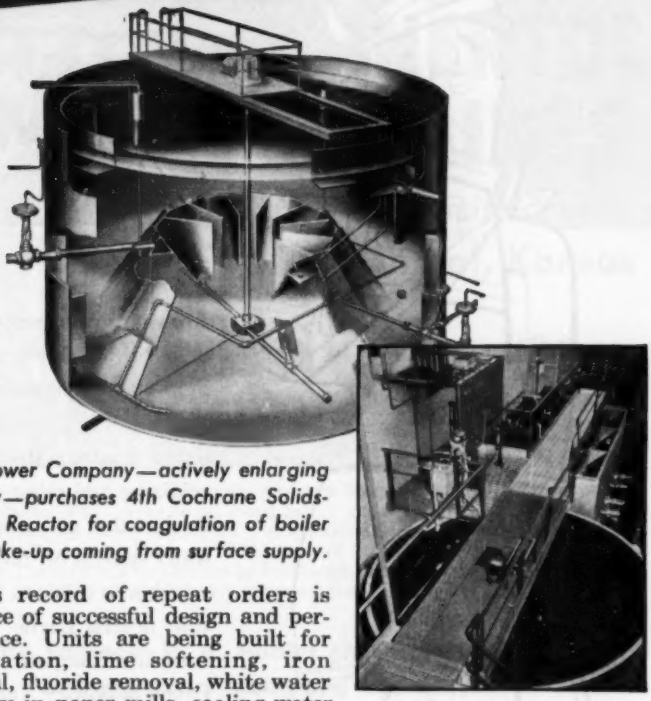

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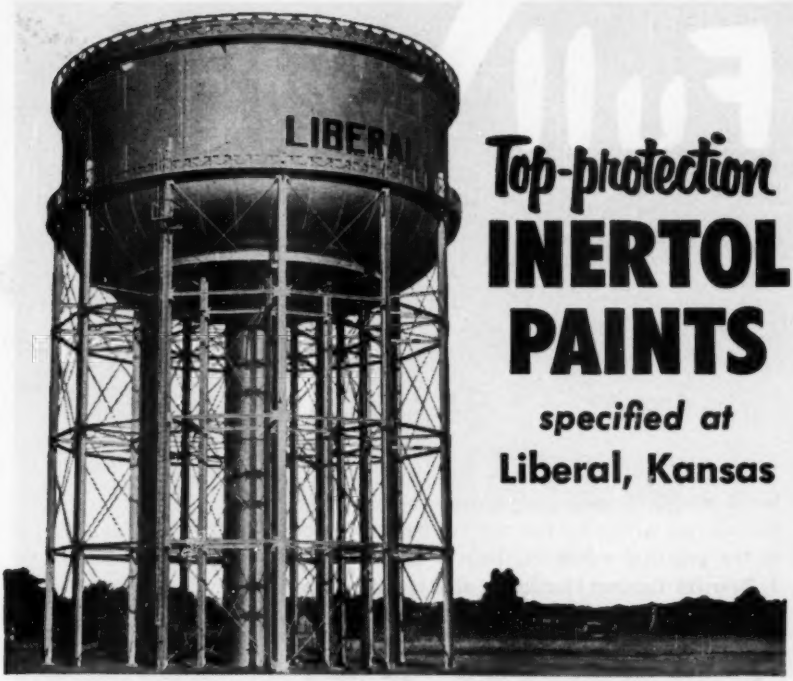

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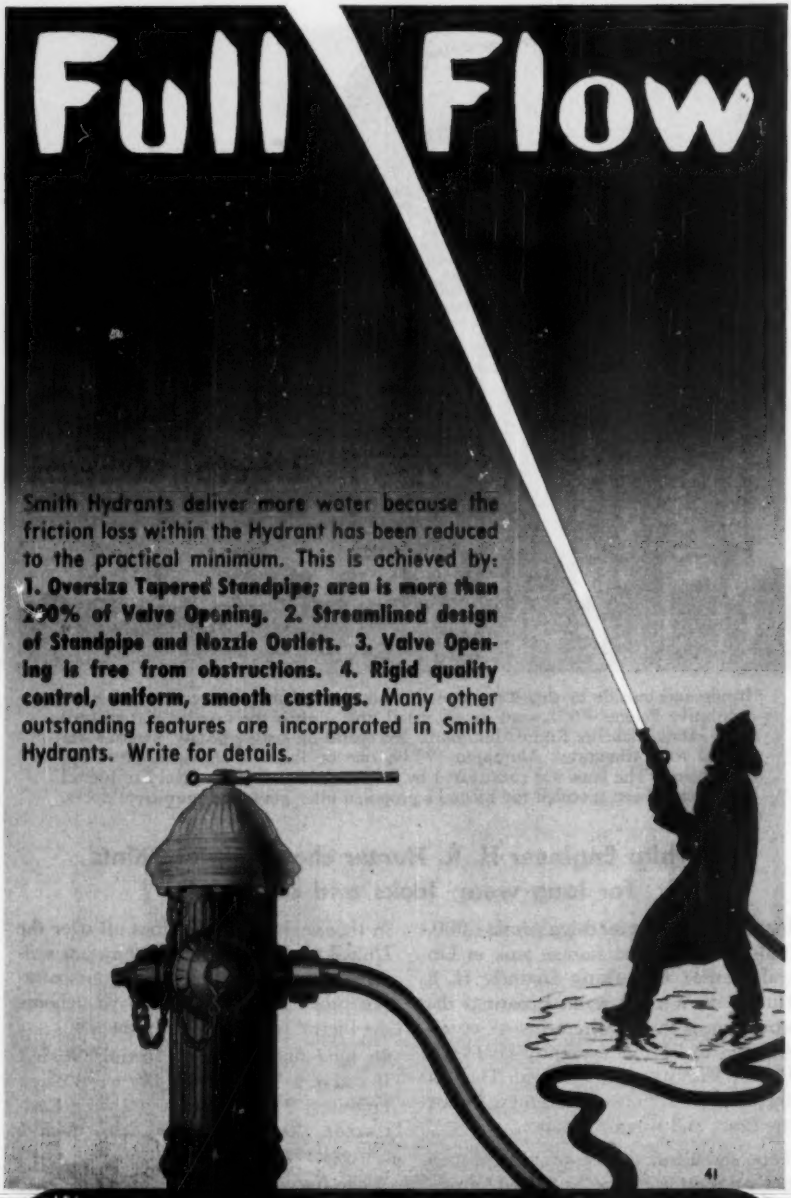

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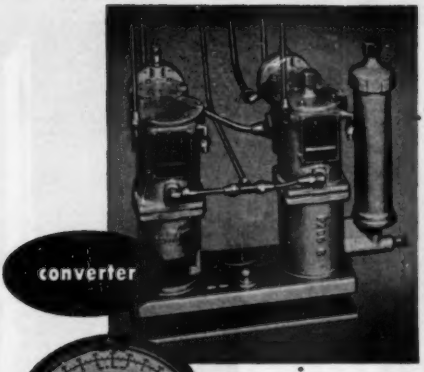

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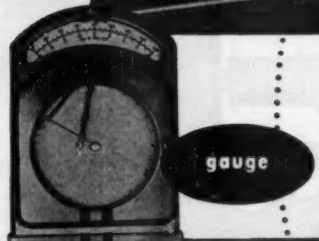
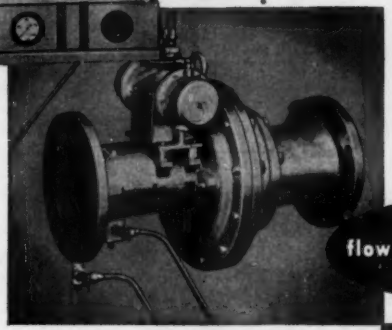
SYSTEM

instant, accurate measurement of head and flow... plus automatic flow control!





Your operation is only as efficient as your measurement and control methods. The C.-A.-P. System provides an accurate measure of head loss and flow and an instantaneous, automatic adjustment of flow rate. Controlled Air Pressure eliminates inaccuracies of stuffing boxes and complex equipment of diaphragm or mercury operated gauges.

See For Yourself...

get this detailed C.-A.-P. bulletin complete with drawings. Ask for Bulletin 1100-J.

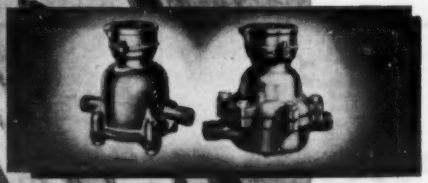
INFILCO

INFILCO INC. | *Tucson, Arizona*

Plants in Chicago & Joliet, Illinois

FIELD ENGINEERING OFFICES IN 26 PRINCIPAL CITIES

WATER
is vital...



BADGER meters conserve it!

America now uses more than *7 billion gallons* of water per day . . . making conservation of supply almost as vital as the water itself. That's one reason Badger meters are used in thousands of communities throughout the nation. Badger meters measure water precisely . . . are made for every kind of water measuring job . . . provide an accurate check of water usage and water waste. And the Badger meter record of performance is unsurpassed . . . has caused waterworks men everywhere to agree — "It pays to install Badger meters!"

BADGER WATER METERS

BADGER METER MFG. CO., Milwaukee 45, Wisconsin

"Measuring the water of the world"

HELLIGE

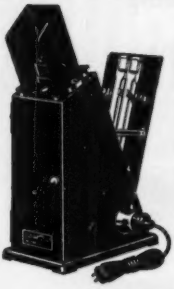
INCORPORATED

877 STEWART AVENUE, GARDEN CITY, N. Y.

HEADQUARTERS FOR
COLORIMETRIC APPARATUS AND
COLOR STANDARDS

DEPENDABLE WATER CONTROL EQUIPMENT
USED WITH CONFIDENCE . . . EVERYWHERE

COLORIMETRIC COMPARATORS
Employing NON-FADING Glass Color Standards for pH & Chlorine Control, and Water Analyses

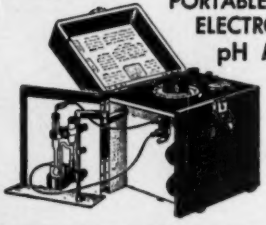


AQUA TESTER for Analyses of Water, Sewage, and Industrial Wastes . . . Employs NON-FADING Glass Color Standards . . . Uses Approved A.P.H.A. and A.W.W.A. Methods for pH, Fluoride, Iron, Phosphate, etc.

TURBIDIMETER
The Turbidimeter **Without** Standards for
- TURBIDITY MEASUREMENTS
- SULFATE DETERMINATIONS

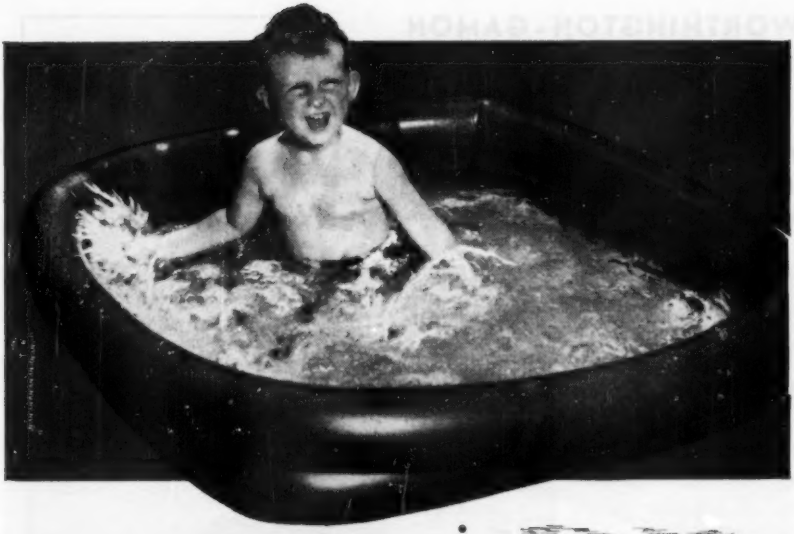
"Chromatron" PHOTOELECTRIC COLORIMETER for Water and Sewage Analyses

PORTABLE ELECTRONIC pH METERS



TWIN-KIT for pH Control and Chlorine or Bromine Determinations of Swimming Pool Water with NON-FADING Glass Color Standards

WRITE TODAY FOR YOUR CATALOGS



no problem with water pressure in Newark!

Since 1934, by using cement lining in its trunk mains, Newark's water flow has been boosted from 57 to 83 million gallons a day.

This was made possible by converting old pipes into new—free of tuberculation and interior corrosion. Here's how it was done: old pipes were hydraulically cleaned, centrifugally machine-lined with mortar cement and smoothed to an even surface. The result: distribution pressure and carrying capacity greatly increased, maintenance costs substantially lowered and life expectancy of pipes extended indefinitely. Entire process done with pipes in place at a *fraction* of the cost of laying new pipes.

CENTRILINE CORPORATION

A subsidiary of Raymond Concrete Pile Co.

140 CEDAR STREET, NEW YORK 6, N. Y.

Branch offices in Principal Cities of United States and Latin America

3,000,000 FEET OF EXPERIENCE

Write today for booklet!

CEMENT-MORTAR LINING OF PIPES IN PLACE

WORTHINGTON-GAMON

WATCH DOG

WATER METERS

The meter used by thousands of municipalities in the U. S.

"Watch Dog" models . . . made in standard capacities from 20 g.p.m. up: frost-proof and split case in household sizes. Disc, turbine, or compound type.

SURE TO MEET YOUR SPECIFICATIONS FOR ACCURACY, LOW MAINTENANCE, LONG LIFE.

Before you invest in water meters, get acquainted with the design and performance advantages which make Worthington-Gamon Watch Dog Water Meters first choice of so many municipalities and private water companies in the United States.

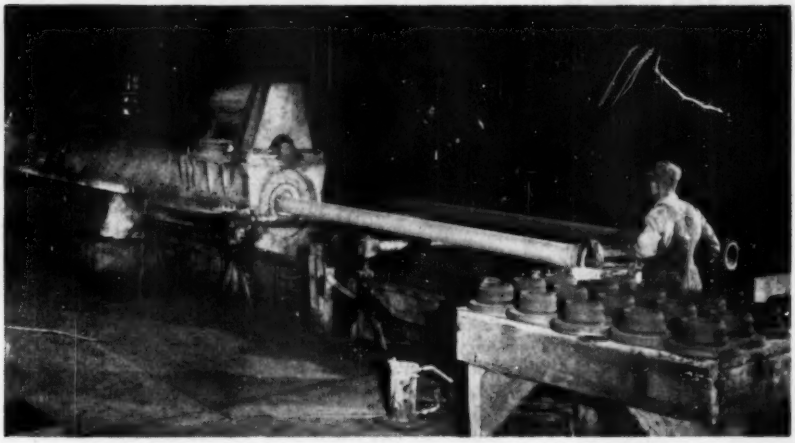
WORTHINGTON-GAMON METER DIVISION

Worthington Corporation

296 SOUTH STREET, NEWARK 5, NEW JERSEY

OFFICES IN ALL PRINCIPAL CITIES

PIG IRON *with a* HOLE IN IT!



Close-up view of pulling a pipe from centrifugal casting machine.

WHY McWANE-PACIFIC CAST IRON PIPE *LASTS for CENTURIES*

Cast Iron Pipe is an engineering product. But the "wag" who jokingly said that Cast Iron Pipe was a "chunk of pig iron with a hole in it" probably spoke with more wisdom than he realized.

Production of pig iron is the first step in refinement of iron ore. As everyone knows, iron ore has laid in the ground for untold ages of time, without rust or corrosion. The more iron is refined, the more subject it is to rust and deterioration. The less it is refined, the more durable it remains. That is why McWane-Pacific Super DeLavaud cast iron pipe, ("pig iron with a hole in it") lasts for centuries.

For details, wire or write McWANE CAST IRON PIPE COMPANY, Birmingham, Alabama, or PACIFIC STATES CAST IRON PIPE COMPANY, Provo, Utah. (Sales offices in principal cities.)

McWANE PACIFIC PIPE *Lasts for Centuries*

WATER Paces Lakeland's Business Growth!

Allis-Chalmers Helps World's

THE "WORLD'S CITRUS CENTER" is being helped by Allis-Chalmers in the race to keep water works ahead of population growth. In ten years, Lakeland's population has increased 70 percent, meters have doubled, and gallonage pumped has nearly tripled!

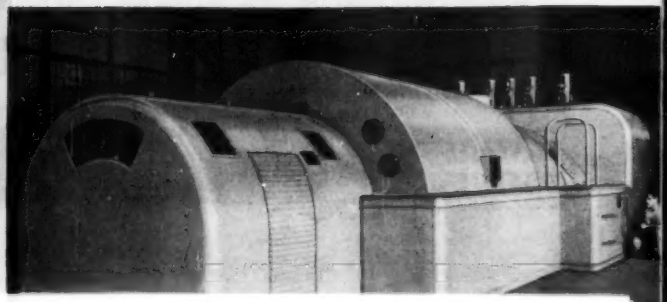
Lakeland is so named because of the 12 lakes within its city limits. It is near the geographical center of Florida, in Polk county . . . producer of a third of all Florida citrus, two thirds of U. S. phosphate, and more cattle than any other county in the state.

Lakeland has learned by experience the wisdom of depending on Allis-Chalmers for a complete range of public works equipment. Some of their A-C equipment has been in operation for over 30 years and maintenance has been "practically nil." A-C equipment at Lakeland ranges from three turbine-generators through transformers, m-g sets, and controls to motors and pumps of many sizes.

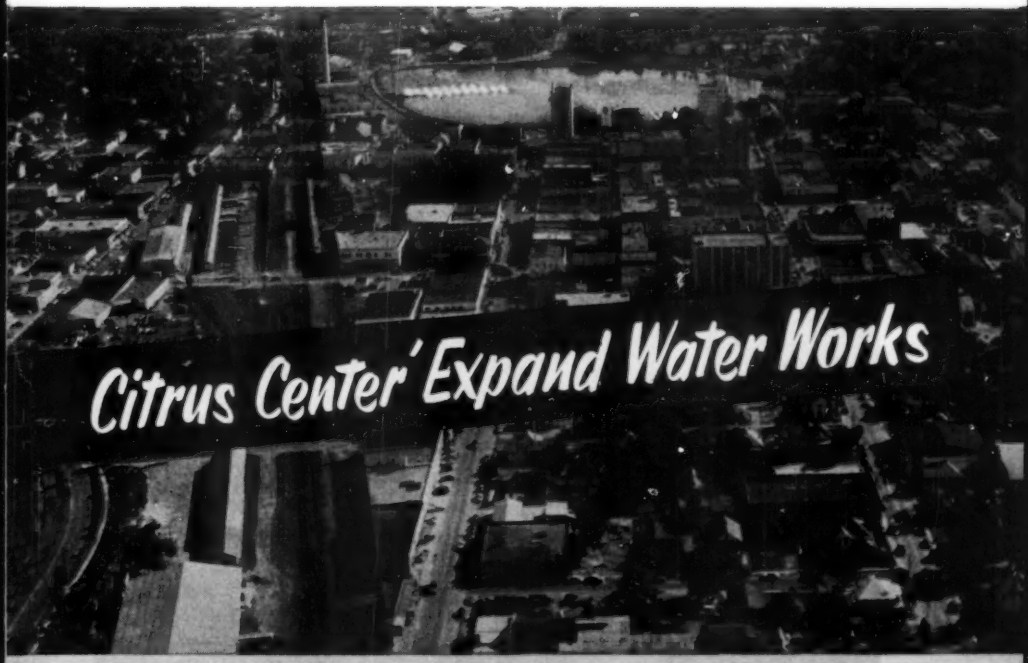
When *your city* plans expansion or modernization, do as Lakeland and other leading cities are doing — take advantage of Allis-Chalmers experience as builder of the world's widest range of public works equipment. Literature on all products available; Public Works Bulletin 25C6607A and Pump Bulletin 08B6146B just off the presses. For your copies, just call your nearest A-C sales office or write to Allis-Chalmers, Milwaukee 1, Wisconsin.

A-4221

POWER TRANSFORMERS were furnished by Allis-Chalmers. Those above are 833 kva, single phase, self-cooled units in Lakeland suburban substation. Other electrical equipment supplied includes controllers for the 150 hp deep well pump motors.



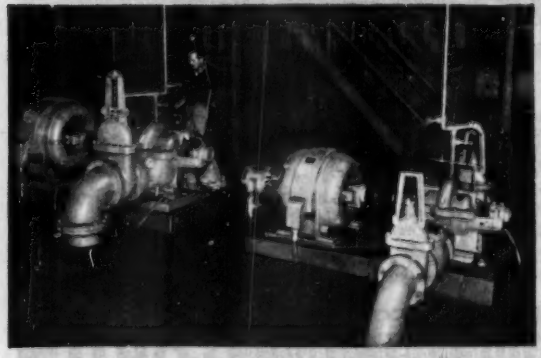
NEW POWER HOUSE features Allis-Chalmers 20,000 kw steam turbine generator unit. In addition to the steam turbine, hydrogen cooled generator, main and pilot exciters, and hydrogen control equipment, A-C also furnished the three 6x4 in., 450 gpm, 1150 psi boiler feed pumps.

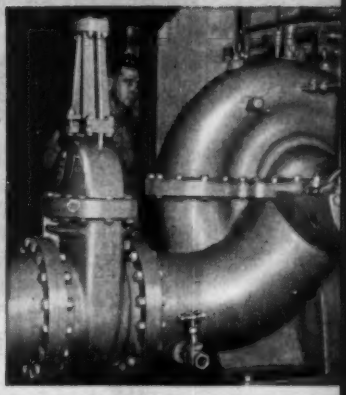


Citrus Center' Expand Water Works

LAKELAND FROM THE AIR, looking east. Over 600,000 people live in a 50 mile radius from Lakeland, Fla. Old power house, containing two Allis-Chalmers 5000 kw steam turbine generator units and associated equipment, is on left shore of Lake Mirror in center of above photograph.

CITY MAINS ARE SUPPLIED by Allis-Chalmers pump-motor teams ranging in capacity from 2000 to 4000 gpm each. Typical setup shown below: at left is a 12 x 10 in. pump rated 4000 gpm at 160 ft head, driven at 1800 rpm by 200 hp motor. At right is a 2000 gpm, 8 x 8 in. pump driven by a 100 hp, 1800 rpm synchronous motor.

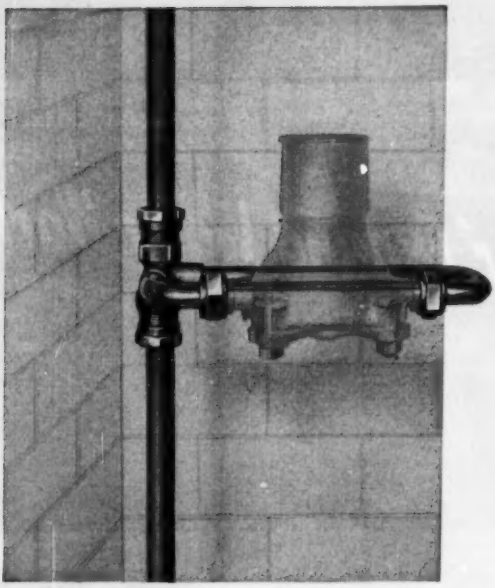




PUMPS RANGE IN SIZE from 1¼ x 1¼ in. to this 16 in., 6000 gpm, 16 ft head unit furnishing condenser cooling water in old power house. Here Allis-Chalmers supplied two 5000 kw steam turbine generator units, boiler feed and condenser circulating water pumps, and crane m-g set.

ALLIS-CHALMERS

Builders of the World's Widest Range of Public Works Equipment



For Setting Meters in Basements

EASY TO INSTALL

The KORNERHORN

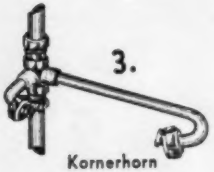
In a vertical basement pipe, against the wall or in a corner, the Kornerhorn makes a most satisfactory meter setting. Installation is fast and economical as pipe threading is eliminated. Send for detailed information.

When Valves are Needed

Ford Kornerhorn valves installed on the supply side, or on both sides of the Kornerhorn add extra convenience and cleanliness when meters are changed.

1. Cut supply line. Clamp not necessary but convenient

2. Add Connections

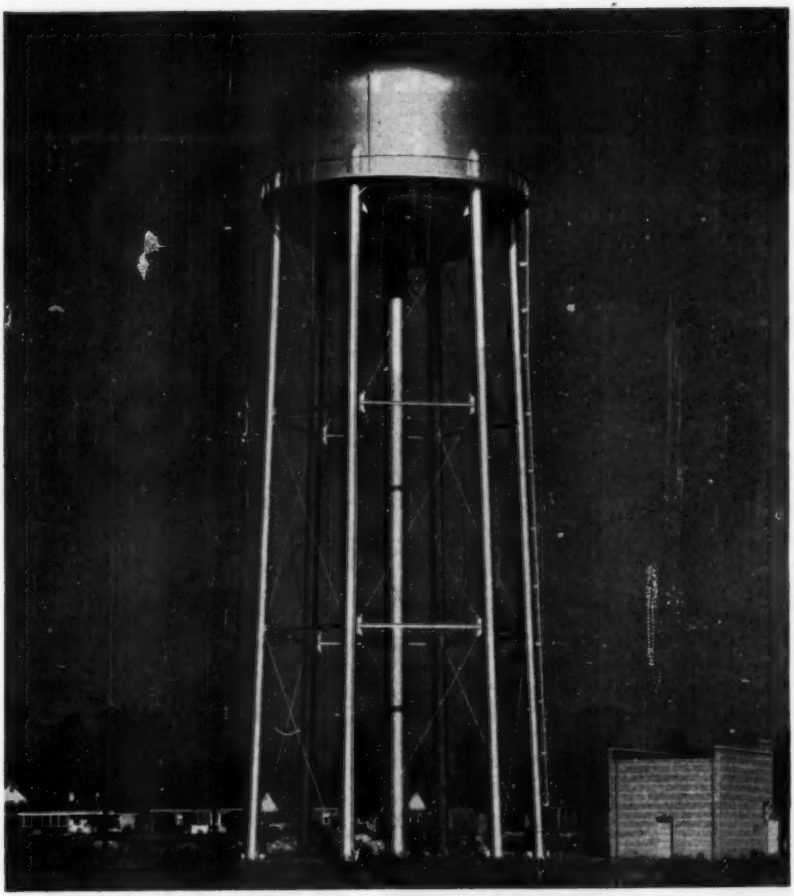


3. Kornerhorn in place

THE FORD METER BOX COMPANY, INC.

FOR BETTER WATER SERVICES FORD

Wabash, Indiana



Third Elevated Tank at Homewood

This modern streamline structure is the third elevated tank we have installed in the water distribution system at Homewood, Ill. It is 250,000 gallons capacity and 105½ ft. to bottom. The steel used in building this tank was pickled to remove the mill scale and painted with a special priming coat to provide a superior bond between the metal and the final coats of paint. Pickling and painting by the Horton process reduces maintenance costs and lengthens the life of a structure.

CHICAGO BRIDGE & IRON COMPANY

Plants in Birmingham, Chicago, Salt Lake City and Greenville, Pa.

BIRMINGHAM	CHICAGO	TULSA	BOSTON	SALT LAKE CITY
PHILADELPHIA	NEW YORK	DETROIT	SEATTLE	LOS ANGELES
SAN FRANCISCO	HOUSTON	ATLANTA	CLEVELAND	PITTSBURGH

In Canada—HORTON STEEL WORKS, LIMITED, FORT ERIE, ONT.

THE MEMBERSHIP OF A C. I. P. Century Club

96%
OF ALL 6-INCH AND LARGER CAST IRON WATER MAINS OVER LAID IN 25 REPRESENTATIVE CITIES ARE STILL IN SERVICE.
Based on the findings of a survey conducted by leading

CAST IRON PIPE

DISTINGUISHED CLUB... now has 60 Members!

The Cast Iron Pipe Century Club is probably the most unusual club in the world. Membership is limited to municipal, or privately-owned, water and gas supply systems having cast iron mains in service for a century or more. Although the Club is formally constituted, there are no dues, no regular meetings, and no obligations other than to inform the Recording Secretary if and when the qualifying water or gas main is taken out of service, or, sold for re-use.

In spite of the unique requirement for membership, the Club roster grows, year by year, from 18 in 1947 to 60 in 1954. And why not, when a survey sponsored by three water works associations, indicates that 96% of all 6-inch and larger cast iron water mains ever laid in 25 representative cities are still in service. And when answers to a questionnaire, mailed to gas officials in 43 large cities, show that *original* cast iron mains are still in service in 29 of the cities.

If your records show a cast iron main in service, laid a century or more ago, the Club invites you to send for a handsome framed Certificate of Honorary Membership. Address Thomas F. Wolfe, Recording Secretary, Cast Iron Pipe Century Club, Peoples Gas Bldg., Chicago 3, Illinois.

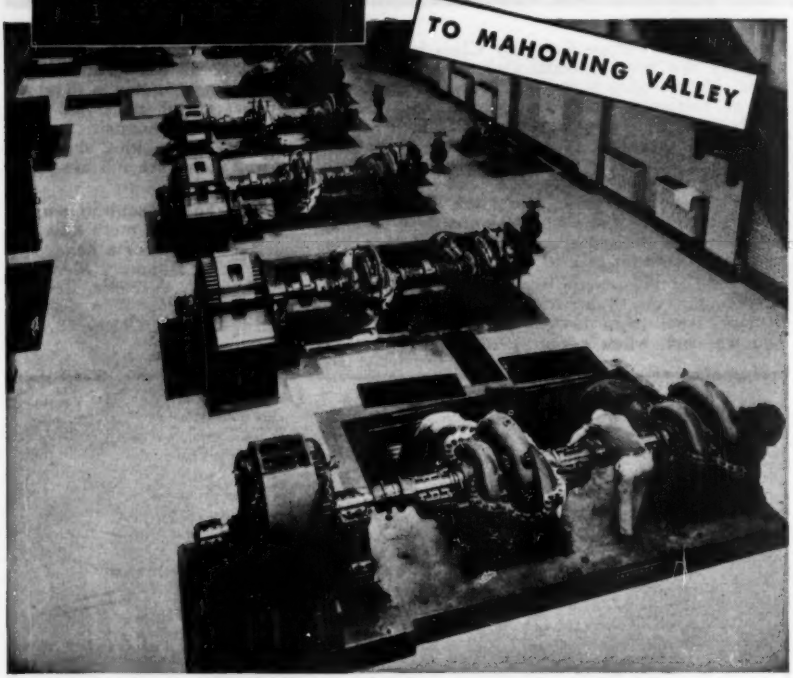
CLUB ROSTER

DEPARTMENT OF WATER AND WATER SUPPLY
City of Albany, New York
NIAGARA MOHAWK POWER CORP. (GAS)
Albany, New York
ALEXANDRIA WATER COMPANY
Alexandria, Virginia
BUREAU OF WATER, DEPT. OF PUBLIC WORKS
Baltimore, Maryland
CONSOLIDATED GAS ELECTRIC LIGHT AND POWER CO.
Baltimore, Maryland
PUBLIC WORKS DEPT., WATER DIVISION
Boston, Massachusetts
BOSTON CONSOLIDATED GAS CO.
Boston, Massachusetts
PUBLIC SERVICE ELECTRIC & GAS CO.
Bound Brook, N. J.
BRIDGEPORT GAS LIGHT COMPANY
Bridgeport, Conn.
DEPARTMENT OF PUBLIC WORKS, DIVISION OF WATER
Buffalo, New York
SOUTH CAROLINA ELECTRIC & GAS CO.
Charleston, S. C.
PEOPLES GAS LIGHT & COKE COMPANY
Chicago, Ill.
WATER WORKS DEPARTMENT
Chicago, Ill.
BOARD OF WATER COMMISSIONERS
Detroit, Michigan
MICHIGAN CONSOLIDATED GAS CO.
Detroit, Michigan
FALL RIVER GAS WORKS COMPANY
Fall River, Massachusetts
CITY OF FREDERICK WATER DEPT.
Frederick, Maryland
GAS DEPARTMENT
City of Fredericksburg, Virginia
PUBLIC SERVICE COMMISSION
City of Halifax, N. S., Public Water Supply
THE HARTFORD GAS COMPANY
Hartford, Connecticut
MUNICIPAL WATER WORKS
Huntsville, Alabama
BUREAU OF WATER
Lancaster, Pennsylvania
LOUISVILLE GAS & ELECTRIC CO.
Louisville, Kentucky
CITY OF LYNCHBURG WATER DEPARTMENT
Lynchburg, Virginia
NATURAL GAS SERVICE, INC.
Madison, Indiana
MOBILE GAS SERVICE CORP.
Mobile, Alabama
MOBILE WATER WORKS COMPANY
Mobile, Alabama
QUEBEC HYDRO-ELECTRIC COMMISSION
Montreal, Quebec
WATERWORKS DEPARTMENT
City of Nashville, Tennessee
PUBLIC SERVICE ELECTRIC & GAS CO.
New Brunswick, N. J.
NEW HAVEN GAS COMPANY
New Haven, Conn.
NEW ORLEANS PUBLIC SERVICE, INC. (gas)
New Orleans, Louisiana
PUBLIC SERVICE ELECTRIC & GAS COMPANY
Newark, New Jersey
DEPT. OF WATER, GAS & ELECTRICITY
New York, New York
PHILADELPHIA ELECTRIC CO., GAS DEPT.
Norristown, Pa.
CITY OF PAINESVILLE, GAS DIST. DEPT.
Painesville, Ohio
DEPT. OF PUBLIC WORKS, BUREAU OF WATER
Philadelphia, Pennsylvania
PHILADELPHIA GAS WORKS CO.
Philadelphia, Pennsylvania
BUREAU OF WATER, DEPT. OF PUBLIC WORKS
Pittsburgh, Pennsylvania
PLYMOUTH GAS LIGHT COMPANY
Plymouth, Mass.
POTTSVILLE WATER COMPANY
Pottsville, Pennsylvania
PROVIDENCE GAS COMPANY
Providence, Rhode Island
QUEBEC POWER COMPANY, GAS DIVISION
Quebec, Canada
BUREAU OF WATER
Reading, Pennsylvania
DEPT. OF PUBLIC UTILITIES (gas)
Richmond, Va.
DEPT. OF PUBLIC UTILITIES (water)
Richmond, Va.
ROCHESTER GAS & ELECTRIC CORP.
Rochester, N. Y.
WATER & SEWERAGE DEPARTMENT
City of Saint John, N. B.
DEPT. OF PUBLIC UTILITIES, WATER DIVISION
St. Louis, Missouri
SALEM GAS LIGHT COMPANY
Salem, Mass.
WATER DIVISION, Dept. of Engineering
Syracuse, New York
THE CONSUMER'S GAS CO. OF TORONTO
Toronto, Ontario
DEPT. OF PUBLIC WORKS
Troy, New York
CITY OF UTICA, BOARD OF WATER SUPPLY
Utica, New York
CITY OF WHEELING WATER DEPT.
Wheeling, West Virginia
WILMINGTON WATER DEPT.
Wilmington, Delaware
WATER DEPARTMENT
City of Winchester, Virginia
WATER DEPARTMENT
City of Winston-Salem, North Carolina
YORK WATER COMPANY
York, Pennsylvania
WATER DEPARTMENT
City of Zanesville, Ohio

SERVES FOR CENTURIES

DE LAVAL
CENTRIFUGAL
PUMPS

bring a new high in water supply



With the addition of a new De Laval 20 mgd centrifugal pump at the Mahoning Valley Sanitary District in Ohio, the station now has a pumping capacity of 60 mgd plus stand-by. This pumping capacity provides for the future program requirements of the water treatment plant.

Vitally important is the fact that the additional facilities were installed without major building alterations or interruptions of service.

The story of De Laval Centrifugal Pumps is one of nation-wide significance, for De Laval units have been serving the districts, large cities and small towns of America for more than half a century. Efficient De Laval Centrifugal Pumps for water works service are available in capacities from 100 thousand gallons per day to more than 100 million gallons per day.

DE LAVAL *Centrifugal Pumps*

DE LAVAL STEAM TURBINE COMPANY
822 Nottingham Way, Trenton 2, New Jersey

DL197A

how much does it cost to stand pat?

It isn't often that a new development comes along that affects chlorine handling – in fact, not in the past 35 years has there been news as important as this to you and your community.

You may feel it costs you nothing to let new developments in chlorine handling go by the board.

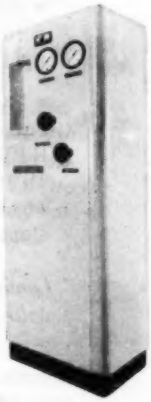
But it costs your community plenty—in money, in better chlorination and in better, safer handling methods.

An Entirely New Way To Chlorinate

Not in 35 years has such a completely new, easy operating, dependable and economical chlorinator been made. The reason is that materials that could remain inert to corrosion were not yet invented.

The most positive way to chlorinate is by means of the diaphragm regulator principle. But until these corrosion resistant materials were invented, a regulator could not be made that lasted against corrosion. The regulator principle is successfully used in the F & P chlorinator, along with such new products as Uscolite, Kel-F, Hastelloy, Teflon, and such timeless materials as silver and tantalum.

Old fashioned, out-of-date chlorination equipment uses vulnerable water seals, whereas in the F & P unit, chlorine is always handled in fully enclosed, tightly sealed, corrosion resistant pipes and components.



You owe it to yourself and your community to know about this dependable, safe, less costly way of handling chlorine. Complete facts, fully illustrated, will be sent to you if you will request them now as well as free trial offer and facts on one year IRON-CLAD guarantee.

complete process instrumentation

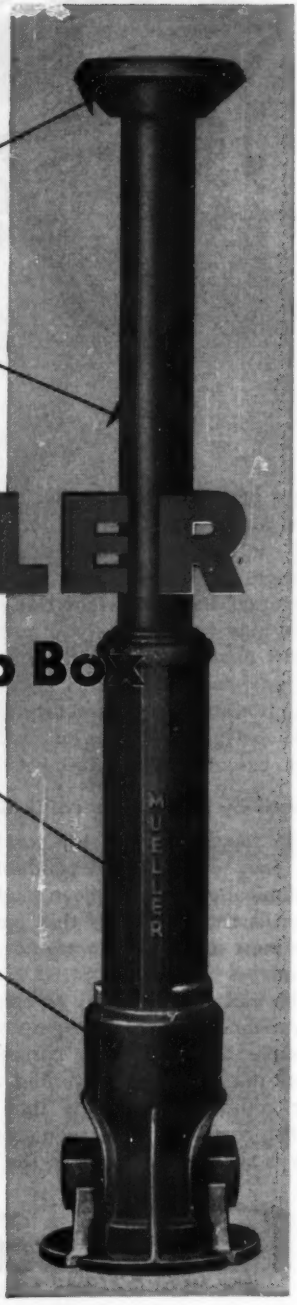
FISCHER & PORTER CO.

*T. M., F&P Co.

5110 Fischer Road, Hatboro, Penna.

2205

Company owned sales and service branches strategically located throughout the world.



• Cast iron lid screws onto large, steel upper section. Pentagon access plug screws into a bronze bushing which is fitted into lid. Assures easy removal of plug in all kinds of weather. 2" diameter upper section offers easy accommodation for large, heavy-duty shut-off rods.

• Steel upper section telescopes into bottom section. Prevents damage to curb box as well as curb stop when subjected to vehicle traffic. Can be furnished in varying lengths from 2' to 5'.

MUELLER

Improved Curb Box

• Arch-type base extends well below curb stop and rests on foot pieces or rigid foundation.

• The H-10316 Curb Box, used with curb stops ½" through 1", and the H-10336 Curb Box, used with curb stops 1¼" through 2", have optional foot pieces which offer close fitting support for curb stops and centers them in the curb box.

Contact your Mueller representative or write direct for detailed information.

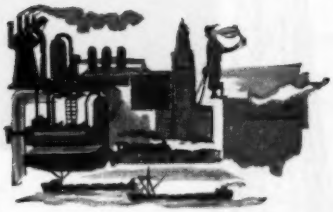
MUELLER CO.

Dependable Since 1857

MAIN OFFICE & FACTORY DECATUR, ILLINOIS

2285 *Company owned sales and service branches strategically located throughout the world.*

Cleveland Prefers Concrete Pressure Pipe



Economy was a decisive factor in Cleveland's selection of concrete pressure pipe for its water supply system. This seventh ranking city in the nation, with an average daily water consumption of 272 mgd., found that the low original cost of concrete pressure pipe, together with its remarkably long life and excellent flow characteristics, made it a sound investment.

In 1940 the first concrete pressure pipe was laid in Cleveland. Since that time several additional installations have been made, one of these being the Nottingham intake. Here, 10,000 feet of 120 inch concrete pressure pipe was used. Just recently the Northfield Road Main was completed. This job, stretching for over 4 miles, used concrete pressure pipe in diameters ranging from 30 to 42 inches.

Efficient, economical concrete pressure pipe is available in a wide range of diameters and can be installed to fit the individual requirements of large or small communities.

Water for Generations to come

Concrete PRESSURE Pipe

AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION
228 North LaSalle Street
Chicago 1, Illinois

well "founded" beauty...

The Eiffel Tower's 984 feet of delicate, graceful beauty has stood the test of time because the interlaced ironwork structure is firmly anchored to four concrete corner-foundations.

with W&T Chlorinators, too...

... Both the beauty of their smooth, modern lines and their time-proved, always dependable accuracy are well founded in the essentials of reliable equipment: — adequate research and development, a trained field staff, modern manufacturing techniques and a full line of designs to meet every need.

Take, for example, the research and development staff. Trained chemists and engineers are working continually to solve new problems with chlorination: to improve existing processes; and to design new equipment and controls. This staff is behind each W&T Chlorinator — your assurance you will get the *best in equipment* and the latest in plant processes.

3-52

WALLACE & TIERNAN
COMPANY INC.
25 MAIN ST. BELLEVILLE 9, N. J.

Journal
AMERICAN WATER WORKS ASSOCIATION
VOL. 46 • JANUARY 1954 • NO. 1

Corrosion by Water at Low Flow Velocity

By T. E. Larson and R. M. King

A contribution to the Journal by T. E. Larson, Head, and R. M. King, Asst. Chemist; both of Chemistry Subdiv., State Water Survey, Urbana, Ill.

UP to the present there has apparently been no organized program for studying corrosion by fresh water. No pattern has been established even to define a corrosive water under various conditions of use.

The saturation index (*1, 2*) for calcium carbonate has been devised and applied with the intent of providing a thin, controlled scale or film of calcium carbonate on the metal surface, thereby reducing or preventing corrosion. The saturation index indicates the tendency toward, but not the rate of, deposition or solution of calcium carbonate in a water, and does not necessarily show corrosivity, a fact that many water works chemists have long recognized.

The current practice appears to be either: [1] to assume that a water is corrosive and to treat it whether necessary or not; or [2] to assume that it is not corrosive until "red water" troubles develop or equipment failure is experienced, and then to apply the corrective treatment that seems most likely to succeed.

In 1924 Whitman, Russell, and Altieri (*3*) concluded from careful experiments with Cambridge, Mass., water that, in the pH range 4.1–10 at 22°C and 4.3–9 at 40°C, hydrogen ion concentration has no effect on the rate of corrosion, and the main variable in this pH region is the rate at which dissolved oxygen diffuses to the metal surface. This conclusion was not intended to apply to waters of other mineral character, but it has been variously misquoted or enlarged upon to imply that dissolved oxygen controls the rate of corrosion in natural waters. The latter interpretation of the Cambridge results was proved incorrect by Baylis (*4*) in 1926. He demonstrated the practical value of calcium carbonate protection by controlled pH and the low solubility of ferrous carbonate at a pH greater than 8.

Because, in reality, each addition of caustic or acid to adjust the pH of Cambridge water produced a water of different mineral quality, the conclusions reached by Whitman and his colleagues need not be applicable to water of the same mineral quality as that at Cambridge or to potable waters in general.

Long experience has taught water works personnel the value of pH control for corrosion protection, but it has also shown that factors other than pH and dissolved oxygen influence corrosion rates. Data available in the form of mineral analyses have not been amenable to interpretation owing to the lack of experimental evaluation.

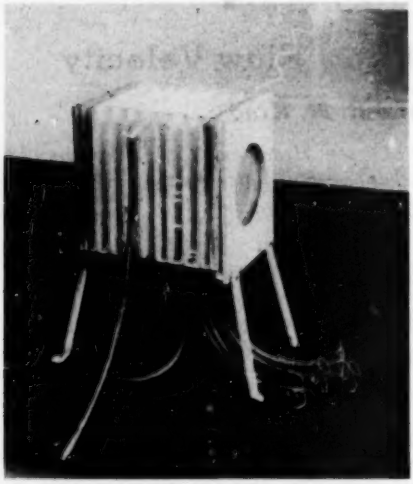


Fig. 1. Experimental Corrosion Cell

The electrolysis cell is divided into nine compartments by alundum plates between the two iron electrodes.

It is the purpose of this paper to demonstrate that water quality is a primary factor in corrosion (specifically at low flow velocities) and that the influence of dissolved oxygen and pH on corrosion rates is secondary. It is believed that the data presented will provide a basis for comparison with information obtained in future studies and in practical experience.

Qualitative Studies on Ion Migration

An elementary investigation was begun in 1948, with the assistance of John Grench of the Illinois Water Survey Div., to obtain qualitative data on the water composition at the cathode and the anode, as affected by waters of different mineral composition. The investigation was designed to study the general water quality conditions that develop between two iron electrodes under the influence of an artificially impressed voltage to produce a current density of a limited magnitude. The electrodes were located at opposite ends of an electrolysis cell divided into nine 470-ml compartments by vertical, parallel porous alundum plates (Fig. 1). University of Illinois

TABLE 1
Tap Water Composition

Item		Amount	
		ppm	*epm**
Iron	(Fe)	trace	
Manganese	(Mn)	trace	
Calcium	(Ca)	60.0	3.0
Magnesium	(Mg)	24.0	2.0
Sodium	(Na)	46.0	2.0
Silica	(SiO_2)	19.0	
Fluoride	(F)	0.3	
Chloride	(Cl)	6.0	0.20
Nitrate	(NO_3)	0.2	
Sulfate	(SO_4)	9.6	0.20
Alkalinity (as $CaCO_3$)		330.0	6.60
Hardness (as $CaCO_3$)		250.0	5.00
Dissolved oxygen		6.0	
Temperature		55° F	
pH		7.4	

* Equivalents per million.

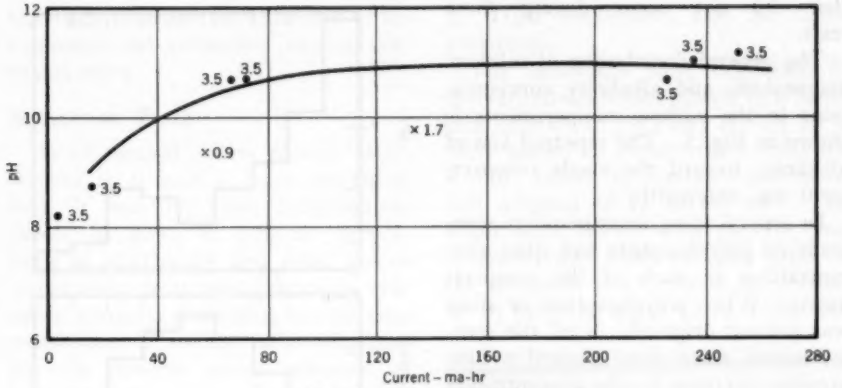


Fig. 2. pH at Cathode

The numbers at scattered points represent the current density in milliamperes per square foot.

tap water was permitted to flow through the center compartment at a rate of 300 ml per minute, while, in the remaining compartments, the water was in a quasi-stagnant condition. No attempt was made to aerate the water or to exclude dissolved oxygen. The composition of the water is indicated in Table 1.

Progressive quality changes occurred in each compartment with increasing milliampere-hours of current consumption. The changes were particularly significant in the end compartments. The increase in pH at the cathode is shown in Fig. 2, and the accompanying reduction in calcium and magnesium in Fig. 3 and 4. It will be noted that, at low current density, the pH was not affected so greatly for equivalent milliampere-hour values, and, accordingly, magnesium precipita-

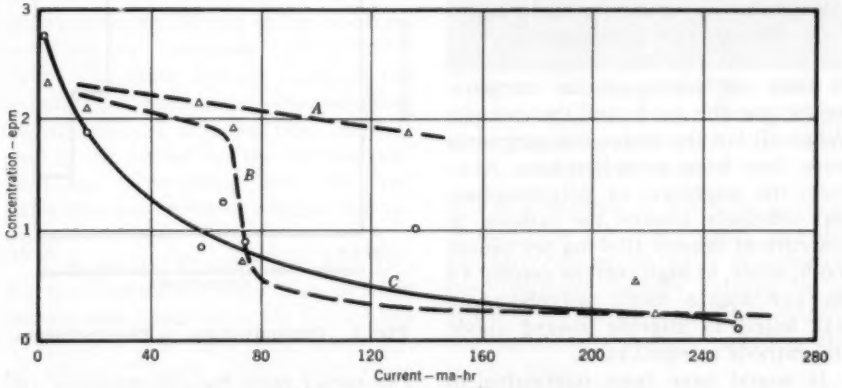


Fig. 3. Magnesium and Calcium Concentration

Key: A—*magnesium, low current density (0.9–1.7) ma per square foot);* B—*magnesium, high current density (3.5 ma per square foot);* C—*calcium.*

tion did not occur during these tests.

The general distribution of calcium, magnesium, and alkalinity concentrations in the various compartments is shown in Fig. 5. The repeated loss of alkalinity toward the anode compartment was noteworthy.

In several tests, measurements were made on polyphosphate and silica concentrations in each of the compartments. When polyphosphate or silica was present originally in all the compartments, these tests showed a progressive decrease in the concentration

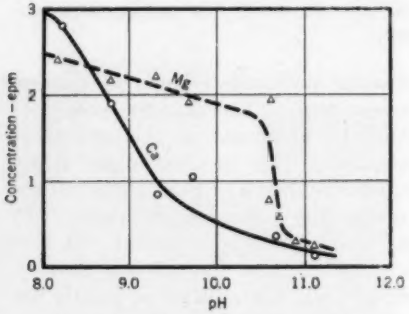


Fig. 4. Concentrations at Cathode

The curves show the concentrations of calcium and magnesium in the compartment adjacent to the cathode.

of these ingredients in the compartments near the anode and the cathode. When all but the center compartments were free from polyphosphate, however, the migration of polyphosphate was definitely toward the cathode at low current density (0.4 ma per square foot), while, at high current density (4 ma per square foot), polyphosphate was found to migrate toward anode and cathode at equal rates.

It would have been interesting to continue these tests with water containing bicarbonate and more chloride, but it was decided to use a different

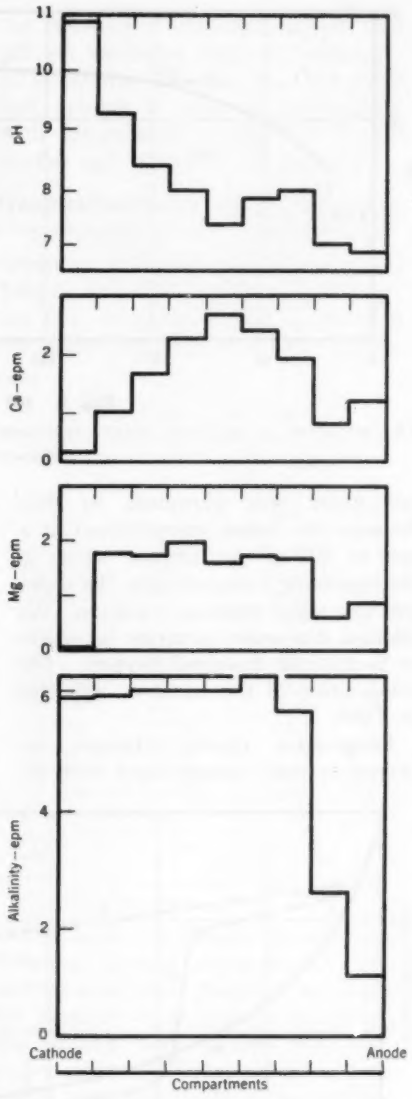


Fig. 5. Concentrations in Compartments

The curves show the concentrations (in equivalent parts per million) of alkalinity, magnesium, and calcium, as well as the pH, in the various compartments.

approach to study the influence of bicarbonate and carbonate ions on corrosion rates.

Immersion Tests

As all natural waters contain bicarbonates in at least a small concentration, it was felt that consideration should be given to different proportions of bicarbonate and other anions in corrosion tests with controlled synthetic solutions containing known concentrations of sodium salts, eliminating the possible added influence of bivalent metal ions. Borgmann (*5*) has indicated the relative corrosiveness of salts of numerous cations and anions, exclusive of bicarbonate and carbonate and largely in concentrations greater than that in natural waters.

The effect of carbonate ions as an inhibitor of corrosion was previously demonstrated by Evans (*6*) in 1927. Mears and Evans (*7*), in 1935, described in detail the inhibiting effect of potassium carbonate on solutions containing potassium chloride. These data, however, concerned strips of steel partially immersed in solutions of known concentrations, and provided no information on the pH of the resultant mixtures of carbonate and chloride salts. In other words, although the potassium carbonate concentration varied, the pH was not held constant and it also varied for the various proportions. Therefore, both pH and carbonate ion variables affected the results.

Apparatus of the standard type (*8*) for total-immersion tests of nonferrous metals was constructed for the studies (Fig. 6). The $1\frac{1}{2} \times 3$-in. specimens of 0.01-in. "black plate" steel (free from mill scale) that were used were reported to have the following composition (by percentage): C, 0.07; Mn, 0.30–0.45; P, 0.015 maximum; S, 0.050 maximum; and Si, 0.010 maximum.

The specimens were degreased in carbon tetrachloride; placed in a 5 per cent solution of HCl and HNO_3 for 2 min; placed in concentrated HCl for 1 min; rinsed in acetone; and dried and weighed 48 hr before use. The edges were coated with paraffin, and a scratch was made on both sides of the specimen just prior to immersion in 18 liters of water for a 3-day test at a flow velocity of 0.085 fps at room temperature. A low velocity was deliberately chosen in order to simulate the conditions usually existing in as much as 25–50 per cent of any municipal distribution system, including the service lines.

Fig. 6. Total-Immersion Test Setup

The specimens used were of black plate steel, free from mill scale. The apparatus was of standard type.

Various proportions of sodium bicarbonate and chloride were used at pH 7 and 9. Likewise, various proportions of sodium bicarbonate and

sulfate were used at these pH values, and various proportions of sodium bicarbonate and nitrate were used at pH 7. Carbon dioxide was employed to control pH. The results are shown in Fig. 7.

Discussion of Results

It was noted that, after the proportion of sodium chloride or sulfate reached a given value, the corrosion rate was not influenced by further addition of these chemicals. Also, the rate was of the same order of magnitude whether chloride or sulfate was used. The corrosion rates with these proportions were therefore assumed to be governed strictly by the dissolved-oxygen content of the water. In other words, if 15 or 20 ppm dissolved oxygen was present, the corrosion rate in this range may have risen, particularly with increasing proportions of sodium chloride.

It was repeatedly found that the corrosion rate was zero when a particular minimum of alkalinity was present in each test. It was also noted that an intermediate range of corrosion existed in which the rate was unpredictable under the experimental conditions. For example, of three specimens in a solution in this range, one may have corroded at a rate of 10 mg per square decimeter per day (mdd), while the two others may have corroded at a rate of 90 mdd in the same solution. In this range of water qual-

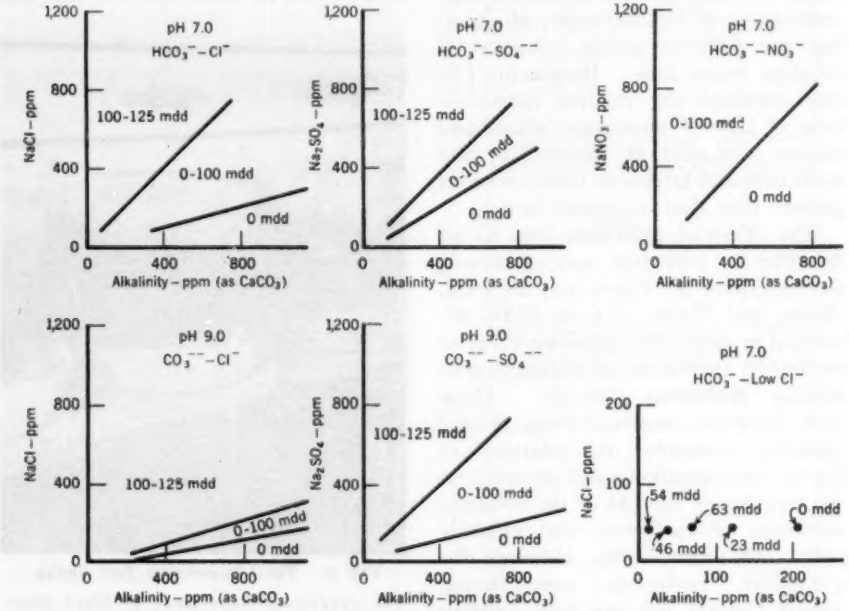


Fig. 7. Results of Total-Immersion Tests

The experiments were conducted at room temperature and constant flow velocity (0.085 fps); the dissolved-oxygen content was 8 ppm. The solid lines represent boundaries of sectors in which the corrosion rates were as shown.

ity, the corrosion rate may have been inhibited or intensified, depending upon the extent and location of the corroded area of the specimen.

It was significant that, for any specific chloride concentration, corrosion rates might be considerably greater for solutions of low mineral content than for those of high mineral content, a finding that is contrary to the usual predictions. It may be concluded that corrosion rates are controlled more by the specific mineral quality than by the total mineral content.

It was also significant that, for some chemical compositions, corrosion rates appeared to be greater at pH 9 than at pH 7, while, for the others, the rates were unchanged. This also is contrary to the normal predictions on the corrosive tendency of water.

The relatively lower corrosion rates experienced with nitrates was surprising. Although a water that contains only bicarbonate and nitrate is a rarity, it should be of interest to make a further study of the effect of small concentrations of nitrate on corrosion rates in water containing various mixtures of chloride and bicarbonate.

Several spot tests with a 9-day immersion period yielded results no different from the 3-day data.

These data are specifically limited to dissolved-solids concentrations between 200 and 1,200 ppm, under the flow velocity and temperature conditions indicated. Figure 7, however, shows the corrosion rates experienced in a test series in which the combined sodium chloride and bicarbonate concentrations ranged from 60 to 210 ppm. Here again, it was noted that the bicarbonate exerted an inhibitive effect. In one group of tests with University of Illinois tap water at pH 7 (-0.4 saturation index), no corrosion was noted until 60 ppm NaCl was present.

Extreme caution is needed in interpreting these data or applying the conclusions to other conditions. Consideration must be given to the fact that, at the low velocities employed in these studies, the electrical migration of ions under the corrosion cell potentials plays a more important part in the process than the relatively slow diffusion rate of the dissolved oxygen. At a higher velocity, it might be expected that oxygen diffusion rates would be the more important factor. Also, the relatively high mineral content minimizes the effect of pH because the hydrogen and hydroxyl ion concentrations are relatively low.

One severe criticism of these data is that no attempt was made to distinguish between general corrosion and pitting. Where pitting occurs, the rate of penetration may be quite high, although the corrosion per square decimeter of the total surface may be no greater than in areas where general corrosion is experienced. Mears and Evans (*7*), however, have shown that pitting is less likely to occur where little or no anodic inhibitor is present.

The data obtained in the study under discussion appear to be particularly significant as a starting point or basis of comparison for future studies. Such investigations might involve lower quantities of dissolved oxygen, higher flow velocities, different temperatures, polyphosphates, silicates, free or combined chlorine, and even calcium at concentrations approaching or exceeding its solubility as calcium carbonate.

Inhibition by Bicarbonate and Carbonate

Normally it is contended that, in air-saturated solutions which do not corrode, the dissolved oxygen has been responsible for the formation of an

invisible oxide film. Evans (*9*) cites many studies with electron diffraction and X-ray techniques which indicate films of ferric oxide. In fact, steel treated with pure oxygen for a sufficiently long period under proper conditions remains corrosion resistant until the film is broken or attacked.

It has often been stated that the corrosion product adjacent to the metal is ferrous hydroxide. It is extremely doubtful that this assertion holds true when carbonate or bicarbonate ions are present. Although the ferrous hydroxide theory may be perfectly correct when dealing with corrosion products derived from solutions of sodium chloride, the actual initial corrosion product is soluble ferrous chloride, hydrolyzed insoluble ferrous hydroxide being secondary.

It will be noted in Fig. 8, however, that the solubility of ferrous carbonate is considerably less than that of ferrous hydroxide, although it is obviously greater than that of ferric hydroxide.

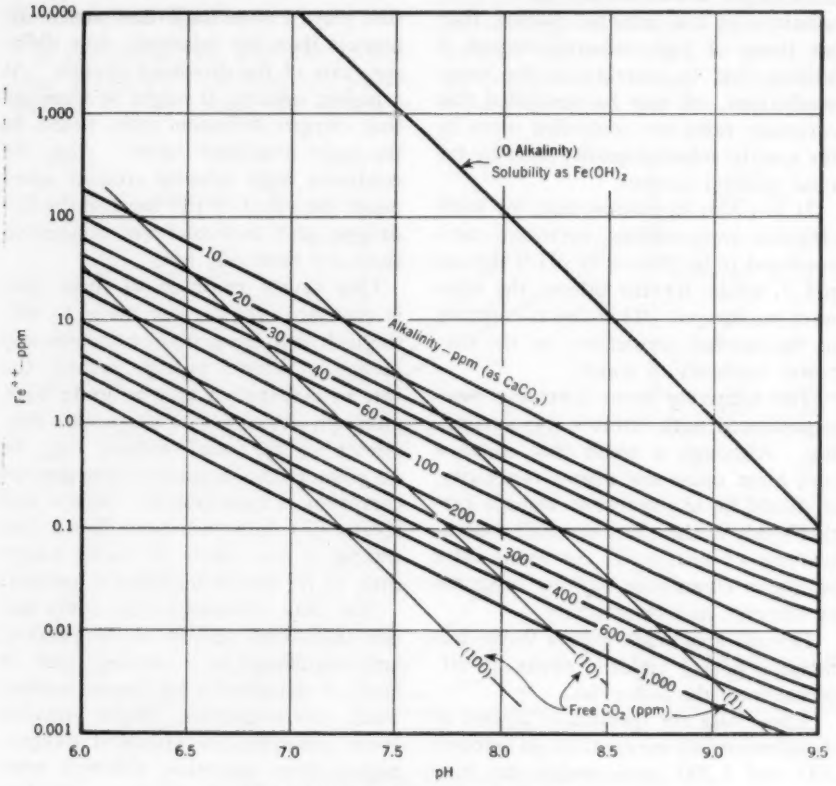


Fig. 8. Solubility of Ferrous Ion

The solubility of $FeCO_3$ (solubility product, 2.11×10^{-11}) is considerably less than that of ferrous hydroxide in natural waters.

This appears to indicate that any inconsistency in an oxide coating would be protected immediately by ferrous carbonate rather than ferrous hydroxide.

Reconsidering the data that showed greater corrosion rates at pH 9 than at pH 7 for the same mineral quality—and accepting the assumption that ferrous carbonate provides an inhibitory film—the increased corrosion rates at pH 9 can be explained by the fact that ferrous hydroxide is more readily formed at the higher pH and is also more readily oxidized. Such localized precipitates adhering to the metal provide a physical barrier to oxygen diffusion and permit the metal surface underlying them to become anodic to the exposed surface. When sufficient alkalinity (not OH^-) is present, however, the flaws in an oxide coating are protected by ferrous carbonate before the ferrous ion concentration can become large enough to form ferrous hydroxide. The relative structure of ferrous carbonate and ferrous hydroxide and their reactive properties with dissolved oxygen are beyond the scope of this paper.

Summary

1. There is need for fresh-water corrosion research.

2. The experiments described demonstrate the behavior of solutions at corrosion cell electrodes.

3. Basic data have been obtained to which other data can be related in order to provide an organized approach to the water corrosion problem. Natural waters contain a corrosion inhibitor, varying in concentration or proportion from one supply to another. Without basic data on the primary, partial, or total inhibition of this natural ingredient, there is no hope of correlating the observations made on the effectiveness of other inhibitors or methods of treatment against corrosion.

4. A possible explanation has been provided for the inhibitory effect of bicarbonate and carbonate alkalinity.

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Ground Water Law in New Mexico

By Charles D. Harris

A paper presented on Sep. 23, 1953, at the Rocky Mountain Section Meeting, Santa Fe, N.M., by Charles D. Harris, Special Asst. Attorney General, State Engr.'s Office, Roswell, N.M.

LEGISLATION dealing with the conservation and use of water resources should take into account pertinent geologic and hydrologic principles. Therefore, before discussing the development of ground water law, it is appropriate to outline the physical theory involved.

In any area where ground water is held in natural storage, it is assumed that the water level remains essentially constant, except for fluctuations induced by climatic conditions, and that the natural discharge is equal to the recharge; in other words, the aquifer is essentially in a state of equilibrium (*1*). It is also believed that the aquifer will continue in this state until a change in recharge or discharge occurs, through either natural means or the works of man. As can be readily seen, any extraneous influence upon the aquifer must, of necessity, be followed by a readjustment of the water in storage in that aquifer.

If it is assumed that all other factors remain constant and that the only change in the aquifer system is the introduction of a withdrawal rate in excess of that naturally existing, the equilibrium of the system may be reestablished by an increase in recharge equal to the amount of the additional withdrawal or by a similar decrease in natural discharge. Otherwise, the additional draft upon the system will result in storage depletion and water level decline. If the additional draft on the system is continued, the aquifer will ultimately become depleted.

The work of Theis (*2*) and others in the field of ground water hydrology has shown that the water level decline in an aquifer is dependent upon the rate of pumpage and the hydrologic characteristics of that aquifer. These investigators have also demonstrated that the approximate water level lowering to be expected after any given length of time can be predicted if these hydrologic characteristics are known.

It is patent that, in any irrigation economy, it is physically impossible to continue to withdraw a greater amount of water out of storage than is being replaced by recharge. The principle guiding the western lawmakers is how best to utilize water resources and at the same time give reasonable protection to those who have property rights based upon the use of water. The fallacy under which the lawmakers have labored is that ground water can be extensively used without eventually reducing the amount available. This fallacy is apparent in the various statutes and is even more obvious in court decisions.

Correlative Rights

The initial stage in the development of the law of percolating waters was characterized by the common-law rule that underground water belonged absolutely to the owner of the overlying land. In the author's opinion, this doctrine is self-contradictory because an aquifer might thus "belong" to several landowners, none of whom had any remedy against a neighbor draining all of the water from it. Any law is meaningless if it sets forth a right without a remedy. To correct this fatal flaw, various jurisdictions developed the American rule of reasonable use. The earliest changes were in the East. The first western decision was handed down in California in 1903, in the case of *Katz* v. *Walkinshaw* (*3*). This was the beginning of the famous California doctrine of correlative rights.

This doctrine accords to the owners of land overlying water supplies rights of use that must be reasonable with respect to each other, each proprietor being entitled to a proportionate part of the total available supply in the event of shortage. In a recent case (*4*), the judgment accorded to all parties, whether overlying landowners or appropriators, rights of use measured solely by a proportionate reduction of the amounts of water they had been pumping, the total annual pumpage from the basin being limited to the safe yield. This decision was based upon the theory that the landowners and appropriators who continued to pump after the commencement of the overdraft, and who, by lowering the water level, interfered with the future possibility of the pumping of full supplies by each other, obtained or preserved rights to continue to pump some water in the future.

Theis has suggested a practicable code for using the correlative-rights theory. He feels that, in each basin, it should be determined how much water can be pumped to provide a safe yield for a reasonable length of time. If it were found that the amount which can be allocated to each acre per year is not sufficient for beneficial use, every landowner would be given the right to concentrate his water on fewer acres. The author believes that the correlative-rights doctrine is subject to certain valid criticisms: [1] no protection is given to those who have spent their time and energy in developing the use of ground water; and [2] a landowner could, merely by owning the property, have a water right without any necessity of ever exercising it.

Prior Appropriation

New Mexico is irrevocably committed to another doctrine—that of prior appropriation—which is chiefly distinguished by the principle that the ownership of the water is vested in the public. No water rights are obtained solely by ownership of land. Beneficial use is the basis, the measure, and the limit of the right to the use of the water. As was pointed out in the report of the President's Water Resources Policy Commission (*5*):

> New Mexico, while not the first state to enact ground water legislation, has pioneered in this field, in that its ground water administrative statute, after having been declared unconstitutional and subsequently reenacted in correct form, was the first of the western state ground water statutes to be put into active operation and has set the pattern for much of the

subsequent legislation in that field in the West.

An example of the effect that New Mexico legislation has had on the ground water law of the West is the "Uniform Underground Water Law for Western States" promulgated by the Assn. of Western State Engrs. in 1934. The similarity to the New Mexico code is striking.

The first New Mexico statute, enacted in 1927, was overthrown by the New Mexico Supreme Court in the celebrated case of *Yeo* v. *Tweedy* (*6*). Although the court held the statute invalid because it violated a constitutional prohibition against legislation by mere reference to preexisting legislation, the court went on to state that the statute was declaratory of existing law, was not subversive of vested rights of owners of lands overlying the waters of an artesian basin the boundaries of which had been ascertained, and was fundamentally sound.

At the 1931 session the present law was enacted. The pertinent statutes are short and to the point and are contained in three pages of the *Annotated Statutes*. Section 77–1101 provides that bodies of ground water with reasonably ascertainable boundaries belong to the public and are subject to appropriation. The statute further provides: "Existing water rights based upon application to beneficial use are hereby recognized." There is also a provision for forfeiture of rights after 4 years' nonuse. According to the administrative provisions of the act, an applicant for a permit to appropriate must apply to the state engineer, who must cause a notice of such application to be published in order that the public and prior appropriators will be advised. If objections are filed, the state engineer conducts a hearing. Whether any protests have been filed or not, the state engineer must grant the application unless he finds that there is no unappropriated water or that the appropriation will impair existing rights. Under the law as it has been administered, all appropriations, changes of water rights, changes of method of use, and changes in well location or construction require a permit from the state engineer. By this procedure, all records involving the use of underground waters are maintained in one state office.

Until 1949 the state was hampered in its administration of ground water law by the absence of legislation dealing specifically with well drillers. To remedy this deficiency, the 1949 session of the legislature passed a law which provided that well drillers operating in basins designated by the state engineer must obtain a license from that official and post a $5,000 bond with him. It was made unlawful for an owner to permit drilling except by a licensed driller. Furthermore, the regulations of the state engineer prohibit the driller from sinking a well unless the landowner has a permit issued by the state engineer. This statute has proved of immeasurable value in curbing illegal drilling.

For almost 20 years after the passage of the ground water law of New Mexico, there was no serious court challenge to its constitutionality. In 1949, however, the validity of the entire act was questioned in the case of *State* v. *Dority* (*7*). The defendants claimed that, as they had acquired title to their land through United States government patents which did not reserve the water, the defendants were the owners of the land and the water

underlying it. The court held that, since the passage of the Desert Land Act of 1877, federal patents of land did not carry with them any title to the water:

> The Desert Land Act provided that all waters upon the public lands except navigable waters were to remain free for the appropriation and use of the public. It was not intended to be taken literally that such water must be upon the surface of the earth to be of such use. The waters of underground rivers with defined banks have always been subject to appropriation. We conclude that all water that may be used for irrigation was reserved by the Desert Land Act to be used beneficially by the public as provided by the laws of the arid states. No interest in such waters was conveyed by United States patent. The United States Supreme Court has always looked to the laws and decisions of the state courts to determine the extent to which the authority of the state over such water has been exercised.
>
> No right to the use of water from such sources was obtained by its use by defendants in violation of law nor can it be. The statutory method of securing such rights is exclusive.

Administrative Problems

Despite the existence of a body of ground water law in New Mexico, as set out in the cases and statutes summarized above, water administrators are faced with numerous problems for which there are few, if any, precedents. The New Mexico Supreme Court has stated (*6*): "New appropriations may . . . be made only from supply not already in beneficial use. Nonuse involves forfeiture. A great natural resource is thus both utilized and conserved." Yet, to the author's knowledge, no court has discussed the problem of how water can be both used and conserved. For example, if the underground reservoir in the Lea County Basin were emptied, it would take 30 centuries to refill it at the present rate of natural recharge, which is estimated to be approximately $\frac{1}{4}$ in. per year. The program of irrigation in the High Plains area of New Mexico and Texas has had a negligible effect on the amount of discharge, so that, for all practical purposes, the recharge and discharge in that area have remained constant. Therefore, all water used for irrigation must come from storage. Some hydrologists have pointed out that the appropriation of water from such natural storage reservoirs is the same as mining the water. Whatever the legal theory, water cannot be pumped from such an underground basin in perpetuity.

New Mexico law provides that, if the state engineer finds that there is unappropriated water or that further appropriation will not impair existing rights, he must grant new permits. But how is he to determine that there is unappropriated water? The ground water laws have been based upon concepts applicable to surface waters. For a surface stream, it would be easy to say that all the water is appropriated when there is none left to flow downstream; in other words, it might be said that a stream is fully appropriated when the appropriation equals the amount of recharge. In an underground storage basin like that of Lea County, however, none of the water could be utilized if the basin were considered fully appropriated when the appropriation equaled the amount of recharge.

This problem was squarely presented in two cases (*8, 9*) now pending before the district court of Lea

County. In both cases, the plaintiffs filed applications with the state engineer to appropriate ground water from the Lea County underground basin. The state engineer denied their applications on the grounds that there was no unappropriated water and that additional appropriations would impair existing rights. At the time of the trials, the state engineer testified that he considered a basin such as Lea County's to be fully appropriated when there was only enough water remaining in storage to allow the prior appropriators a reasonable amount of water for a reasonable length of time. He explained to the court that there is no way in which the water of a storage basin can be utilized so that the appropriators will have a right to its use in perpetuity.

The problem is indeed perplexing, and the lawmakers and courts need the fullest cooperation from ground water specialists. Many students of the problem believe that an irrigation economy should last for at least 40 years, a period that is usually considered the maximum for farm loans and is commonly employed to schedule payments under reclamation projects. It would appear that a shorter period would not enable a farmer to make a substantial investment and get a fair return. Community and state investments in roads, banks, schools, trading centers, gins, and the like constitute another economic factor that might well be considered in determining optimum ground water development. Any calculations involving the question of what should be done with ground water resources should take the aquifer characteristics into account, so that the maximum amount of water can be utilized over the maximum length of time. An ideal program would provide for proper spacing of wells and irrigated sections. Under actual conditions, however, this end is hard to achieve because of variations in soil quality and differences in landowners' views on irrigation projects.

Late in 1952 the New Mexico state engineer, after an exhaustive study and an inventory of the amount of water in the Lea County Basin, announced a formula under which some new appropriations could be made in that area. Believing that prior appropriators should be entitled to the use of water for a period of at least 40–60 years, the state engineer has granted permits in those areas where new appropriations can be made with the least impairment to the rights of prior users. In the author's opinion, this program will serve as a good precedent for other water administrators and will ultimately be regarded as a foresighted approach to the problem of conservation.

Nevada Law

From a hydrologic point of view, a 1939 Nevada law contains the most realistic criteria for the administration of ground water that the author has ever encountered:

> It shall be an express condition of each appropriation of ground water acquired under this act that the right of the appropriator shall relate to a specific quantity of water and that *such right must allow for a reasonable lowering of the static water level at the appropriator's point of diversion;* and provided that, in determining such reasonable lowering of the static water level in a particular area, *the State Engineer shall consider the economics of pumping water for the general types of crops growing and may also consider the*

effect of water use on the economy of the area in general; and nothing herein shall be so construed as to prevent the granting of permits to applicants later in time on the ground that the diversions under such proposed later appropriations may cause the water level to be lowered at the point of diversion of prior appropriators, so long as the rights of holders of existing appropriations can be satisfied under such express conditions. The State Engineer at any time may hold a hearing on his own motion or upon a petition signed by a representative body of users of underground water in any area or subarea, to determine whether the water supply within any area or subarea is adequate for the needs of all permittees and all vested-right claimants; and, if the determination is negative, the state engineer shall order that withdrawals be restricted to conform to priority rights during the period of shortage. In any basin or portion therein designated by the state engineer as herein provided, the state engineer may restrict drilling of wells in any portion thereof if he determines that additional wells would cause an undue interference with existing wells; provided any order or decision of the state engineer so restricting drilling of said wells may be reviewed by the district court of the county. [Author's italics.]

The administrators of ground waters in New Mexico and other jurisdictions that do not have a comprehensive ground water code should, perhaps, adopt criteria similar to Nevada's if permitted under the discretion or regulatory powers delegated to them by the legislature.

Determining Impairment of Existing Rights

It is difficult not only to determine the legislative meaning of unappropriated water in a storage basin, but also to arrive at a sound basis for deciding whether a new appropriation will impair existing rights. It is common knowledge that pumping from a body of ground water, whether or not under artesian head, creates a cone of depression which affects the water level of other wells in the area. If prior appropriators have the right to continue to produce water from the same depth as when they made their initial appropriation, the development of ground water resources will be vastly curtailed. Thomas and Fiedler (*10*), in an article on legal control of ground water, commented on two Idaho decisions:

> There is no indication in the decisions that the defendants set up as their justification that by the laws of nature it would generally be impossible for any subsequent user of ground water to pump from the same water-bearing formation without affecting to some degree the water level and yield of every well previously installed in the area. Carried to an ultimate conclusion, these decisions might mean that in many areas the first appropriator could require damages from every subsequent appropriator, and each subsequent appropriator, in turn of priority, could require damages from all later appropriators, until the last one would have to pay tribute to all. If the doctrine of appropriation is to accomplish the desired end of making full use of the ground water resources of the state, it must be recognized that some lowering of the water table or of the artesian pressure is a reasonable result of a reasonable method of diversion (pumping) of the water, and should not constitute a basis for damages.

It seems obvious that, if the New Mexico ground water statute affords the first appropriator the right to have the water level maintained at its initial height (or damages in lieu thereof)

even when an adequate and economically usable water supply of equivalent quantity is available at greater depths, this interpretation would unduly complicate the administration of water rights in the state and might seriously obstruct the full utilization of the ground water supply. The publication requirement in the ground water law gives the first appropriators knowledge of subsequent applicants. If the prior appropriators do not protest the issuance of a permit, they may be estopped from complaining of a resultant lowering of the water table as long as it is feasible for them to obtain their allocated quantity of water.

Relationship of Ground and Surface Waters

Another problem with which the administrators in New Mexico and other western states have wrestled is the status of ground waters that constitute a part of the base flow of or are tributary to a surface stream. In Colorado, the state supreme court established the doctrine that rights to the use of ground water tributary to a watercourse are correlated with the right to the use of waters flowing in the watercourse itself (*11, 12*). The doctrine of prior appropriation governs these several rights. This means that the first appropriator, whether he diverts from the stream itself or whether he intercepts tributary ground water on its way to the stream, has the first right, and subsequent appropriators, whether they intercept the ground water or divert from the surface stream, are junior in order of priority. In other words, in the logical application of this rule, the location of the point of diversion has no more bearing on the priority of rights to tributary ground water than it has on priorities among appropriators who divert directly from the stream.

The New Mexico state engineer has evidently adopted this theory insofar as the waters of the Carlsbad underground basin are concerned (*13*). In that area, he has closed the basin to further appropriation except by owners of rights to the waters of the Pecos River. They may obtain permits to supplement their surface rights with ground water. The rationale of this procedure is that these waters are part of the base flow of the Pecos River and that all of the water of that stream has been appropriated.

The only New Mexico decision touching upon the interrelationship between ground and surface water was in a case involving the El Paso and Rock Island Railroad Co. (*14*). The company instituted suit in Lincoln County, asking for a general adjudication of all water rights in the Benito stream system. The suit was brought under the New Mexico adjudication statute, which provided that, in any suit for the determination of a right to use the water of any stream system, all those whose claim to the use of such water was of record and all other claimants who could be ascertained with reasonable diligence should be made parties. It was also provided that: "The court in which any suit involving adjudication of water rights may be properly brought shall have exclusive jurisdiction to hear and determine all questions necessary for the adjudication of all water rights within the stream system involved."

While the suit in Lincoln County was pending, appropriators from the Roswell artesian basin brought suit in Chaves County, seeking to enjoin the railroad company's diversion of surface water as being subversive of the

superior rights of the artesian appropriators because the surface waters of the Benito watershed contributed to the recharge of the Roswell artesian basin. The state supreme court issued a writ of prohibition against the Chaves County Dist. Court on the grounds that the Lincoln County Dist. Court had exclusive jurisdiction over the adjudication of the stream system of the Benito River and that the Roswell artesian basin appropriators were proper parties to the adjudication suit as they claimed some right in the water involved.

It follows from this decision that the stream adjudication statute is authority for the adjudication of a ground water basin that is part of a stream system. There has been considerable discussion about whether the water of the Roswell artesian basin could be adjudicated without further legislation. The author believes that it could be but that an adjudication statute is needed to cover all ground water basins, whether or not they are in any way connected with a stream system.

Along the valley fill of the Rio Grande there is a considerable amount of underground water that may be obtained. In 1948 approximately 15,000 acre-ft of water was pumped for municipal and industrial use. Records show that there has been little lowering of water levels and that pumping has not significantly reduced the flood plain evapotranspiration losses. Unless the pumped water is salvaged from the waste, it is inevitable that the flow of the river must be depleted. A study (*15*) conducted by the US Geological Survey in the Elephant Butte district concludes: "The ground water and surface water supplies are interdependent and ground water pumped in the Rincon and Mesilla valleys does not represent an additional supply or new source of water but rather a change in method, time, and place of diversion of the supplies already utilized." As is pointed out, all of the pumpage of the lower Rio Grande comes from ground water that is a part of the base flow of the river. No ground water basin along the Rio Grande has been designated by the state engineer. Most of the wells that have been drilled into the valley fill have been used to supplement Rio Grande surface water. A question that may be the basis for future court battles is the status of the water rights of the appropriators from the valley fill who do not have basic surface rights. If it is assumed that this water is a part of the base flow of the river and that all of the surface water in the Rio Grande has been appropriated, it would appear that these junior appropriators who do not have surface water rights are subject to injunction suits. This situation again illustrates the fact that the lawmakers and the courts have not realized the interrelationship between surface and ground water. The law has placed these types of water in separate compartments, whereas the hydrologists know that each is only a part of the overall hydrologic cycle. The critical condition of water supplies in the West may well cause the time lag between science and law to be fatal.

Conclusions

1. New Mexico has no known extensive ground water areas in which the available supply is sufficient to meet ultimate demand.

2. Neither the legislature, the administrators, nor the courts can grant rights to the use of more water than exists.

3. The state ground water code and the Tweedy (*6*) and Dority (*7*) cases irrevocably commit New Mexico to the doctrine of public ownership of ground water and the prior appropriation system of administering water rights.

4. The field of ground water law is yet in its infancy and there still remains a need for judicial determination and interpretation of many phases of the law.

5. Any official actions—whether legislative, administrative, or judicial —affecting water resources should be guided by the principle of maximum utilization with maximum protection for prior users.

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Determining the Percentage of Induced Infiltration in Multiple-Well Discharge

By E. Bruce Meier

A paper presented on Apr. 16, 1953, at the Nebraska Section Meeting, Lincoln, Neb., by E. Bruce Meier, Asst. Prof. of Civ. Eng., Univ. of Nebraska, Lincoln, Neb.

THE utilization of the water resources of the nation is receiving increased attention. Interest in this subject will continue at a high level because the competition for water is becoming keener. There is a real need for reevaluating and increasing knowledge about this resource. One topic of importance in this regard is the induced infiltration of ground waters.

Surface waters infiltrate adjacent ground water bodies when pumping of the latter lowers the water table. As this phenomenon requires direct, reversible communication between the surface stream and the ground water, the process is dependent upon the continuous presence of the surface water body and of ground water conditions such that, should the wells become inoperative, ground water flow to the stream would soon resume.

Induced infiltration could significantly reduce the flow of a surface stream. Conversely, the withdrawal rate requirements from a well field might be impossible to maintain if the supplemental supply from induced infiltration were removed by either artificial or natural drying up of the stream. Therefore, the quantitative evaluation of induced infiltration is of significant interest.

Recently Lincoln, Neb., accelerated its program of gathering data on its water supply in order to learn as precisely as possible how it would be affected by increased use in neighboring areas. Lincoln's supply is obtained from a well field in the Platte River Valley near Ashland, Neb., and there was evidence that considerable induced infiltration from the river helped sustain the withdrawal rate required. Thus, the municipal supply apparently derived its water from a combination of underground and surface sources.

One phase of this program of correlation and investigation assumed that future upstream irrigation developments might involve the use of all of the river flow at various times during the growing season, so that there would be no surface flow past the Lincoln well field during these periods. The question to be answered was whether a dry river bed would jeopardize the dependability of Lincoln's water supply. Obviously, it was necessary to determine as accurately as possible: [1] the extent to which the well field was drawing upon the river as a source of water and [2] whether the underground valley carried sufficient ground water to supply the well field without induced infiltration from the river.

Although progress in the field of ground water hydraulics has been notable during the past 20 years, little effort has been devoted to the develop-

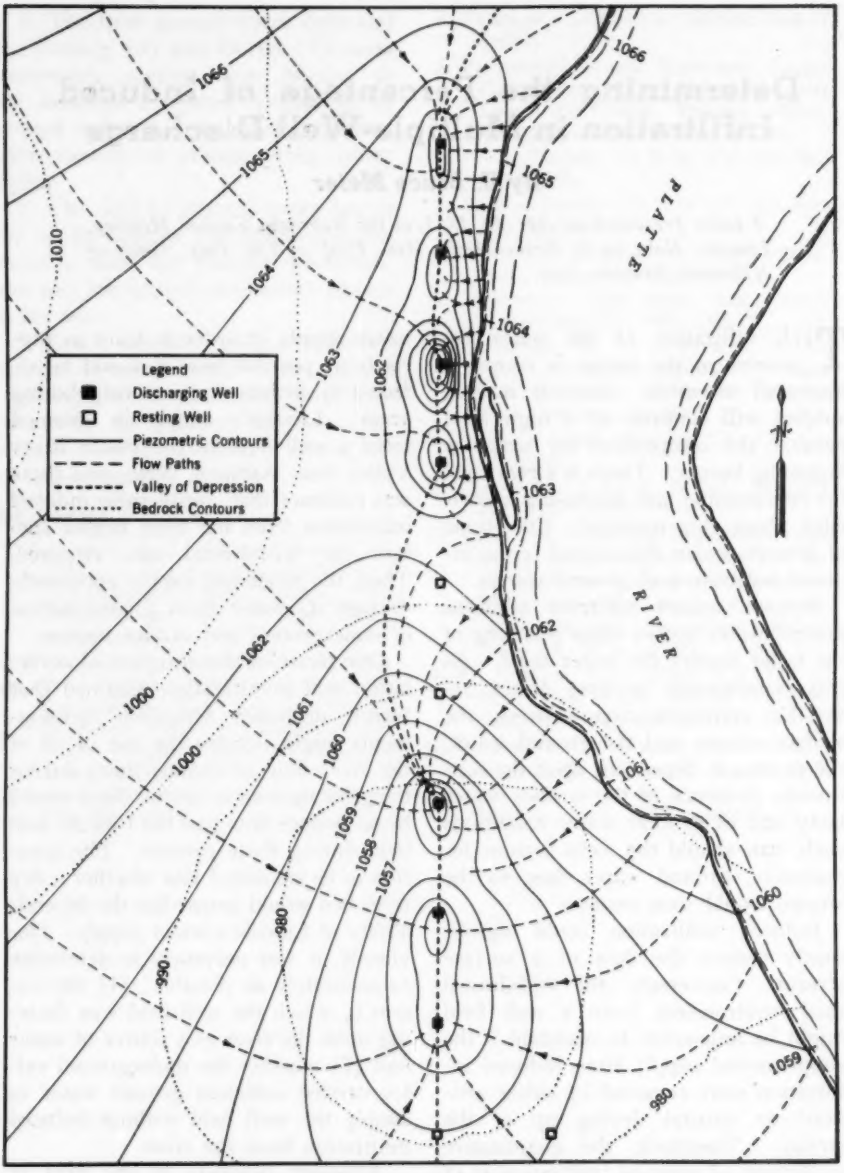

Fig. 1. Lincoln, Neb., Well Field

Flow paths and piezometric and bedrock contours are shown.

ment of procedures for finding the percentage of induced infiltration in multiple-well discharge. Theis (*1, 2*) found a formula by which the effect of a discharging well upon the flow of a nearby stream could be determined. The assumptions upon which this formula was developed include the necessity for continuous pumping at a constant rate. Most well fields are operated in more or less random fashion, however, with no single well discharging continuously for extended periods of time, although there may be continuous withdrawals from the field. Consequently, Theis' equation is not amenable to simple application in this situation.

Whether one well or several are being operated, the general shape of the piezometric surface of the water table becomes established after a relatively short period of pumping, and the flow paths of underground water to the well field become clearly defined.

Observational Data

The Lincoln well field and its relationship to the Platte River are shown in Fig. 1. The river is a typical sand bottom stream with unstable bed conditions. The alluvial materials of the 5-mile-wide valley extend to bedrock at an average depth of approximately 70 ft. A partial cross section is shown in Fig. 2. There is surface flow adjacent to the well field at all times. The flow of the river varies in response to the normal fluctuations in supply and loss and, in addition, is subjected to diurnal variations due to the daily storage and release of water to meet peak load requirements at a hydroelectric power plant upstream, near Columbus,

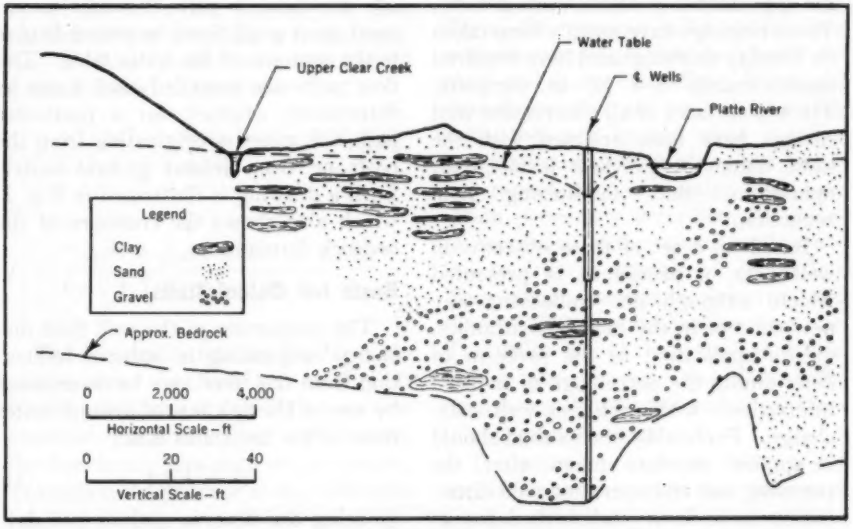

Fig. 2. Partial Geological Cross Section

The reader is looking north at this cross section of the Lincoln well field near Ashland, Neb.

Neb. Thus, there is radiating from the river a constant roll of ground water waves, which manifest themselves in fluctuating water levels at observation wells. The vertical magnitudes of these fluctuations, however, are relatively small, on the order of 0.1–0.5 ft.

Lincoln has maintained a comprehensive observation well program for a number of years. The general policy has been to take monthly readings from the approximately 70 observation wells. These readings have usually been taken on Sunday mornings and have required approximately 3–4 hr to complete. The top surfaces of all observation well casings have been oriented with the same datum by previous level circuit operations, thus minimizing note reduction.

Based on a set of these observation well data, a procedure is presented which, although not embodying any new concept in the field of hydraulics, merits application to the problem of determining the percentage of induced infiltration with multiple-well discharge. Preferably, the method should be applied to data taken after the pumping rate and operating well distribution have been undisturbed for at least 24–48 hr. The observation wells should be strategically located and of sufficient number so that maximum evidence of water table elevations over the field is obtained, and all of these wells must be in free communication with the ground water at all times. Screens on pumping wells should penetrate the entire aquifer depth. Accurate information regarding the elevation and slope of the water surface of the adjacent stream must be available, together with ample information to prepare a map of the well field and stream to some convenient scale. If the bedrock formation is extremely variable in elevation, data should be available so that the depth of the saturated aquifer may be determined at any point.

Using the map described above, the observation well data are plotted and the contours of the water table are carefully drawn. A flow net of the ground water is next prepared, consideration being given to the fact that the direction or path of water movement must at all times be perpendicular to the contours of the water table. The flow paths are extended until it can be determined whether, for a particular path, the water is originating from the river or from inland ground water. Such a drawing is illustrated in Fig. 1, which also shows the contours of the bedrock formation.

Basis for Calculations

The proportion of the well field discharge originating in induced infiltration from the river may be determined by use of Darcy's law of ground water flow. This law states that:

$$Q = KIA \quad \ldots\ldots\ldots (1)$$

Q being the flow, in gallons per day; K the coefficient of permeability, in gallons per day per square foot under a hydraulic gradient of 100 per cent and a water temperature of 60°F; I the hydraulic gradient, in feet per foot; and A the area of flow cross section, in square feet. The validity of Darcy's law for the usual conditions of ground water flow has been conclusively established.

The proportion, P, of well discharge derived from the river by induced infiltration will be the ratio of the total flow carried in the flow net paths originating

in the river to the total flow to the wells:

$$P = \frac{Q_{river}}{Q_{total}} \quad \cdots\cdots\cdots (2)$$

but:

$$Q_{river} = K(I_1A_1 + I_2A_2 + \cdots + I_mA_m)$$

and:

$$Q_{total} = K(I_1A_1 + I_2A_2 + \cdots + I_{m+n}A_{m+n})$$

in which m is the number of flow paths from the river and n is the number of flow paths from the inland ground water. Therefore:

$$P = \frac{K(I_1A_1 + I_2A_2 + \cdots + I_mA_m)}{K(I_1A_1 + I_2A_2 + \cdots + I_{m+n}A_{m+n})}$$

or:

$$P = \frac{I_1A_1 + I_2A_2 + \cdots + I_mA_m}{I_1A_1 + I_2A_2 + \cdots + I_{m+n}A_{m+n}} \quad \cdots (3)$$

The numerical data for Eq 3 are obtained from the flow net in Fig. 1. Under conditions of equilibrium or, for practical purposes, near equilibrium, the flow in any flow path will be steady. Therefore, the product of the hydraulic gradient and the area of flow cross section for all sections of a single path should be equal. Thus, the value of IA for each flow path may be most accurately determined as the mean of several values at different sections of each path.

Values of I used in the computations were obtained by drawing tangents, at appropriate sections, to the longitudinal water surface profile constructed for each path from the contour data in Fig. 1. The corresponding values of A were secured by scaling the path width at the point of water surface slope measurement. The product of the path width and depth from water surface to bedrock yielded the value of A.

In determining the flow paths which originate in the river and those which originate from inland ground water, it must be remembered that, without artificial water table drawdown by pumping, ground water would be feeding into the river by gravity. This must be true if the infiltration from the river during pumping is truly induced. Thus, the general water table slope without pumping would be toward the river and down the valley. When the drawdown due to several pumping wells that are located close together and approximately in a straight line is superposed upon the water table condition previously described, the cones of depression of the several wells overlap to form a trough of depression. This trough intercepts the river and thereby induces infiltration from it. The valley line of the trough is the dividing line between the flow paths originating in the river and those from inland ground water.

The variations in single values of IA for different sections in any flow path are due principally to the impossibility of sketching perfectly consistent contours and flow paths in a reasonable period of time. These inconsistencies are probably compensating rather than cumulative, as the mean value is used for each path and the paths are contiguous and hypothetical in their boundary definitions. Thus, the inconsistencies are not believed to have significant weight in the final result, assuming that reasonable skill and care are demonstrated in the original sketching of contours and flow paths.

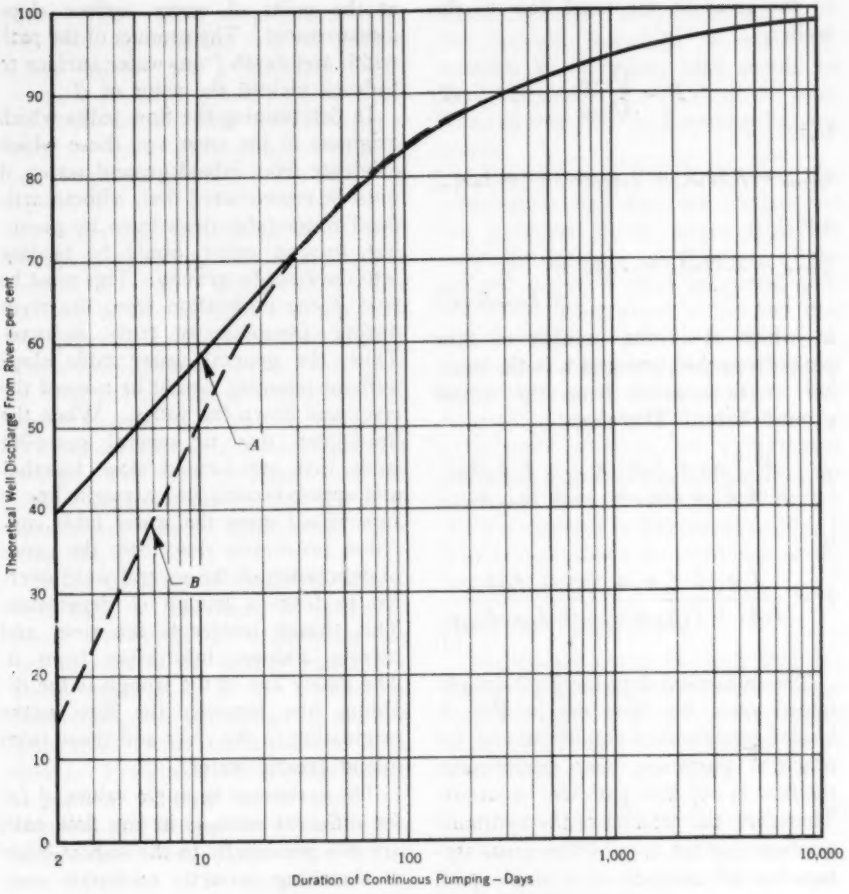

Fig. 3. Theoretical Well Discharge From River

A—*weighted effect of all wells at their true distance from river;* B—*single well at average distance from river.*

For the problem at hand, two product factors were carried in the computations, one assuming constant depth to bedrock (*IW*) and the other being *IA*, previously described. The difference between the two results was insignificant. Except for unusual bedrock formations, bedrock data may be omitted from the computations without serious impairment of the accuracy of the determination.

The method described yields a conservative estimate of the percentage of induced infiltration in multiple-well discharge because it does not account for the intercepted ground water flow that normally would reach the river as ground water runoff. In effect, such

interception is accountable for as induced infiltration, although it does not physically enter the ground water zone from the river.

Results

Substituting the data derived by application of the above procedure to Lincoln's well field at Ashland yields:

$$P = \frac{3{,}693.5}{4{,}572.5} = 0.808 = 80.8 \text{ per cent}$$

Thus, at least 80 per cent of the water withdrawn from the well field originates directly from the Platte River.

Figure 3 is a plot of the Theis equation using a coefficient of transmissibility of 190,000 and a coefficient of storage of 0.17, both values derived for the Lincoln well field. The curve indicates that, theoretically, if the wells of the Lincoln field were located at their true respective distances from a straight reach of the river and if their relative locations with respect to each other were maintained, it would require approximately 75 days of continuous pumping to secure 80 per cent of the well discharge from the river. Consequently, it appears that, although the Lincoln well field has been in operation for more than 20 years, the effect of random cycling of individual wells and of occasional shutdowns of the field produces the same result as if the seven pumping wells in Fig. 1 had been operating continuously for only 75 days.

If a single well were discharging the entire flow and were located as far from the river as the average distance of the seven pumping wells in Fig. 1, it would require approximately 35 days of continuous pumping to reach the induced infiltration rate demonstrated by the several wells pumping continuously at their proportionate rates. The effect after 35 days is the same as for multiple wells.

The author and others have attempted to determine permeability coefficients of the Platte River Valley near Ashland. These efforts yielded results ranging from approximately 2,200 to 2,780, which represents exceptionally good water perviousness. Using the highest value, the existing valley ground water slope, and the valley transverse and average depth dimensions, it has been determined that approximately 3.5 mgd flows down the Platte River Valley past Ashland as ground water. As Lincoln was withdrawing water from the well field at the rate of 12.6 mgd during and before the time of data collection for this study, it is obvious that the dependability of Lincoln's water supply rests on the presence of continuous surface flow in the Platte River past Ashland.

Conclusions

1. The method described for determining induced infiltration yields conservative results.

2. Lincoln's well field secures at least 80 per cent of its supply from the Platte River by induced infiltration.

3. The percentage of Lincoln's water supply obtained from the Platte River by induced infiltration will increase as the well field is expanded and the average daily withdrawal rate is increased.

4. Intermittent periods of zero surface flow past Ashland would seriously jeopardize the dependability of Lincoln's water supply.

Readers desiring further information on the subject of induced infiltration are referred to a number of useful articles in the literature (*3–20*).

Acknowledgment

The author expresses his sincere appreciation to D. L. Erickson, Director and City Engr., Dept. of Parks, Public Property, and Improvements, Lincoln, Neb., for generously contributing the facilities of his department and personnel in securing maps and data. The author is further indebted to the personnel of the Lincoln Water Dept., particularly Alden S. Metcalf and Fred Blumer, for their wholehearted interest and cooperation in the collection and disposition of data.

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Discussion

Alden S. Metcalf

Engr., Eng. Dept., Lincoln, Neb.

Several years prior to the study described by the author in his interesting paper, the Lincoln, Neb., City Engineer's office had made numerous hydrologic investigations of the Platte River well field. One of these studies dealt with the rate of induced infiltration and arrived at approximately the same result as the author by a somewhat different method.

The objective of the study was to determine the magnitude and direction of underground flows in all parts of the well field under typical existing conditions. It was hoped not only to learn the relative amounts of water entering the well field from the underground flow of the valley and from the surface flow of the river, but also to find an average coefficient of permeability. This information was needed to assess the effects of a proposed expansion program for the Lincoln water works

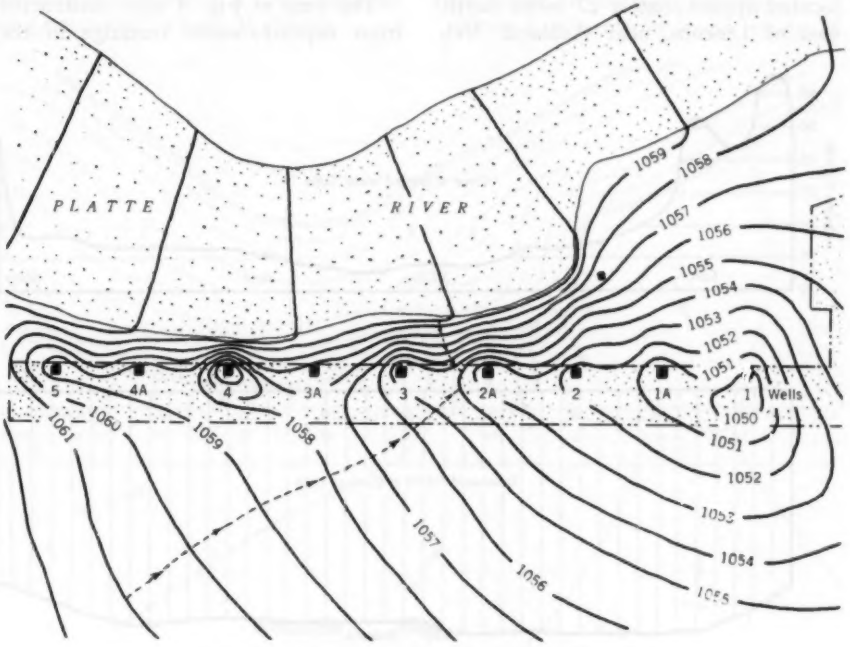

Fig. 4. Ground Water Contours, Dec. 22, 1948

These contours for the Ashland, Neb., well field were constructed from observation well readings. Bedrock contours, also considered in the study, are omitted for the sake of clarity.

system which called for the installation of a large number of new wells in the vicinity of the present well field and a greatly increased total production. It occurred to the writer that routine information already on hand might be sufficient for the purpose, if a suitable method of analysis could be devised.

The well field under discussion is located approximately 27 miles northeast of Lincoln, near Ashland, Neb. was first developed in 1932 and since then has been the principal source of water for Lincoln. December 22, 1948, was the day selected for study because pumping and ground water conditions were then believed to be nearly in equilibrium and because that was the latest date for which the necessary information was complete.

The map in Fig. 4 was constructed from depth-to-water readings in the

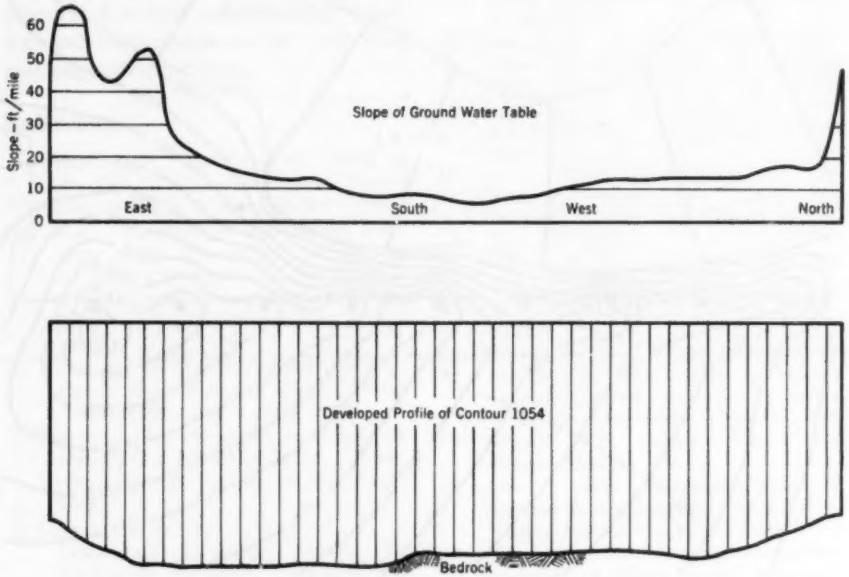

Fig. 5. Water Table Slope and Contour Profile

These diagrams apply to Contour 1054. The developed profile is 2.35 miles long, has an average depth of 71 ft and an area of 880,000 sq ft. The value of ΣIA *is 3,086 sq ft.*

At the time of this study there were nine gravel-packed wells, varying from 46 to 90 ft in depth and spaced 1,000 ft apart on a straight north-south line at distances ranging from 400 to 2,400 ft from the west bank of the Platte River. The rated production of each well was either 1,000 or 1,400 gpm, depending on location. The well field

various observation wells. It will be noted that the contours vary somewhat from those found by Meier, owing to different pumping conditions. The Darcy formula, $Q = KIA$ (see page 22) was used as the basis for calculation. In this instance, it was preferred to solve for K. The contours of Dec. 22, 1948, happen to be so arranged that

it was possible to employ a simpler and more rapid method of calculating incremental areas A and transverse slopes I than that used by Meier. It will be noted that Contour 1054 completely surrounds four of the wells. The remaining wells are bounded by Contour 1061, together with flowlines drawn perpendicular to all of the contours, starting at each end of a 200-ft segment of Contour 1054 near Well 2A.

tional to the depth of the bedrock below the water table contour. Transverse slopes, I, were obtained by scaling off distances perpendicular to the contour in question from the next lower to the next higher contour, and dividing the 2-ft difference in elevation by the horizontal distance so scaled off. Values of A and I and their product, IA, were then tabulated for each segment.

From a separate hydraulic study, it

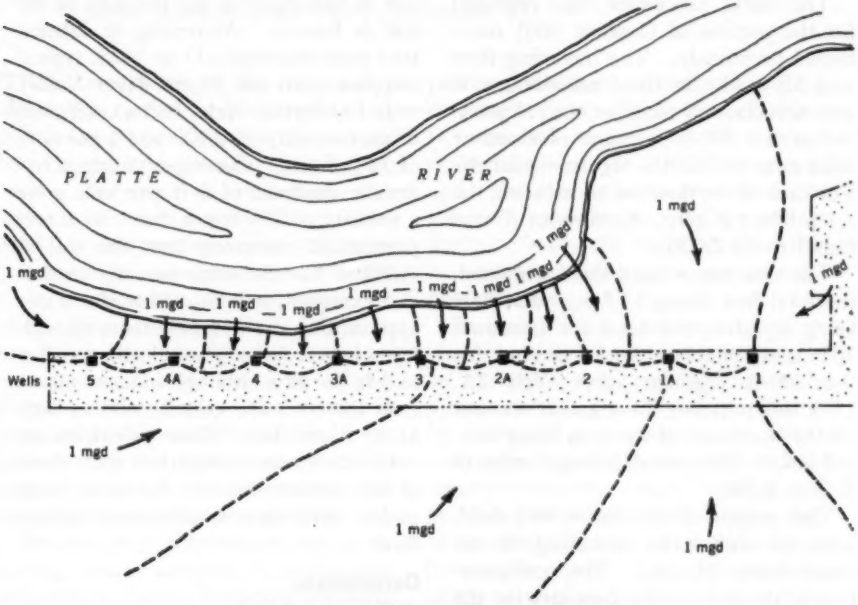

Fig. 6. Ground Water Flow at 14 mgd

Approximately 75 per cent of the total production is found to be the result of induced infiltration from the river.

The total flow into the areas so bounded would be equal to the total pumpage, which at that time was 13.2 mgd. Accordingly, Contour 1054 was divided into 62 equal segments, each 200 ft long, and the useful part of Contour 1061 was also divided into similar 200-ft segments. The incremental areas, A, were then directly proportional to the depth of the bedrock below the water table contour. Transverse slopes, I, were obtained by scaling off distances perpendicular to the contour in question from the next lower to the next higher contour, and dividing the 2-ft difference in elevation by the horizontal distance so scaled off. Values of A and I and their product, IA, were then tabulated for each segment.

From a separate hydraulic study, it was calculated that the four wells surrounded by Contour 1054 were producing 7.4 mgd. It was then possible to derive a coefficient, K, for the neighborhood of Contour 1054 independently. Figure 5 shows the results of this independent determination. It will be noted that the depth of the aquifer did not depart far from the average of

71 ft, but the transverse slopes varied widely. The average coefficient of permeability, K, was 2,400 gpd per unit of area under unit transverse slope. (For laboratory purposes, areas are expressed in square feet and slopes in feet per foot. In the field, however, it is often convenient to consider each unit of area as being 1 mile wide and 1 ft deep, and each unit of slope as being 1 ft per mile.)

The same procedure was repeated for the portion of Contour 1061 mentioned previously. The incoming flow was 5.8 mgd. In these calculations, it was necessary to consider the IA product at the 200-ft segment of Contour 1054 near Well 2A a negative quantity. For each of the flowline boundaries, the IA product is zero. Coefficient K was found to be 2,020.

The two areas were then combined, the total flow being 13.2 mgd and ΣIA being equal to the total for Contours 1054 and 1061, less the IA product for the 200-ft segment near Well 2A. (For this purpose, the segment was not on the boundary of the area being considered.) The overall average value of K was 2,200.

The output of the entire well field, with all nine wells operating, is approximately 14 mgd. The configuration of the water table contours for the 14-mgd condition should be nearly the same as for the 13.2-mgd condition in regions fairly remote from the wells. The map in Fig. 6 was constructed accordingly. It was assumed that the average K value of 2,200 would apply everywhere on the perimeter of the area bounded by Contour 1054 and by part of 1061. The flow into each part of the area would then be directly proportional to the corresponding IA value. Therefore, ΣIA for the entire perimeter was divided into fourteen equal parts, and boundary lines were drawn to show fourteen areas, each of which should contribute 1 mgd to the production of the well field. It will be noted that approximately 3.5 mgd originates from the valley side of the wells and 10.5 from the river side. Thus, 75 per cent of the total production came from the river by induced infiltration.

The velocity of underground flow can be calculated if the porosity of the soil is known. According to laboratory tests reported (*1*) in 1938, typical samples from the Platte River Valley near Lexington, Neb., had a coefficient of permeability of 2,100 and a porosity of 32 per cent. Correspondingly, a hydraulic gradient of 6 ft per mile gave a velocity of 0.99 ft per day. By direct proportion, assuming that the soil at Ashland has the same porosity as that at Lexington, it follows that the water approaching the well field from the valley side was flowing at velocities as low as 1 ft per day, although in some places near the river the velocity was as high as 23 ft per day. These velocities are very small when compared with those of the surface water in the river, even under conditions of minimum surface flow.

Conclusions

The coefficient of permeability of the gravel in the Platte River Valley near Ashland, Neb., is approximately 2,200, which is comparable to that of other locations farther upstream.

The Lincoln well field at Ashland secures approximately 75 per cent of its present production from the Platte River by induced infiltration.

Reference

1. Lugn, A. L. & Wenzel, L. K. Geology and Ground Water Resources of South-Central Nebraska. *USGS Wtr. Supply Papers,* No. 779 (1938).

Engineering Reports for Water and Sewer Systems

By J. Stephen Watkins

A paper presented on Sep. 23, 1953, at the Kentucky-Tennessee Section Meeting, Owensboro, Ky., by J. Stephen Watkins, Sr. Partner, J. Stephen Watkins, Cons. Engrs., Lexington, Ky.

THE importance of the engineering report cannot be overemphasized, as it is the proper basis for the conception, design, and execution of all engineering construction, including, particularly, municipal and other governmental public works. The prime requirements of any report are: [1] that it be sufficiently comprehensive to cover all pertinent aspects of the problem being studied; [2] that it be coherent, clear, and as brief as the subject permits; and [3] that it be written in language readily understandable by the persons who will read it; nontechnical language should be substituted for technical terms whenever possible.

The first step in developing any engineering report consists of exhaustive preliminary studies, including the gathering of all data necessary to the solution of the problem. As a result of these studies, the person who is to write the report must become so familiar with the problem that he has a clear concept of the approach, presentation, and solution prior to taking the next step. A potentially good report can be ruined by trying to write it too soon or too fast. The second step is the detailed planning and design of the report. This involves correlating all pertinent data and arranging it in logical outline form. Next the full report is composed in the form of a rough draft, which is then critically reviewed and refined in order to be certain that the best possible presentation will be made. Finally the report is drawn up in completed form and prepared for presentation.

In general, any good report will include the following main elements: [1] an introduction that plainly states the purpose of the report and the plan to be followed in presenting it; [2] a summary of findings, conclusions, and recommendations (many readers will be more interested in this section than in the detailed and more technical portions of the report); [3] the main body of the report, which is the basis of the summary; and [4] a concluding statement detailing what the report has accomplished.

The main body of the report, in addition to incorporating engineering analyses and solutions for the technical phases of the problem, must also undertake to establish the overall needs for some extended but predictable period, with construction priorities for each phase of the master program, and the economic feasibility and method of

financing of the proposed improvements. The engineer must always keep in mind the financial capabilities of the client, and it is his duty and responsibility to see that the design and costs of the recommended projects are suited to the financial capacity of the owner.

Perhaps the simplest description of an engineering report is to say that it is a document intended for presentation to the client with the purpose of convincing him of: [1] what needs to be done and the benefits to be obtained; [2] how much it will cost; and [3] how it can be financed within the means and fiscal limitations of the client.

Example of Report

The outline of an actual report prepared by the author's firm will serve as an example. This report was made for a Kentucky city of less than 10,000 population and covered a study of needed improvements to the existing municipally owned and operated water and sanitary sewage systems. The completed report was accepted by the municipal authorities and has since become the basis for the financing and continuing construction of a sizable step-by-step program of water and sewer improvements.

As the author's firm had not previously been consultants for this city, the first step was the assembly of extensive data on: the economic character and population of the community; the physical extent and condition of existing water and sewer facilities; the current quantities of water and sewage; the number of service connections; the rates in effect; the historical operating revenues and expenses; and the outstanding bonded indebtedness, including amounts owed, interest rates, redemption provisions, and maturity schedules.

With these data in hand, it was possible to proceed with office studies of present needs and of future requirements (for a period of 25 years, based on predicted population and usage).

The water system studies covered present and predicted consumption, and present facilities and needed improvements for source of supply, treatment, transmission, storage, and distribution. A program of recommended improvements in each category was developed, with an estimate of cost and the establishment of a construction priority for each water subproject. A similar approach was used for the sanitary sewer system.

The next step was to formulate the master program of water and sewer projects by dividing the proposed improvements into three main sections: immediate—those improvements which should be undertaken at once; intermediate—those improvements for which there is an existing or impending need and which should be undertaken as soon as more urgent needs are met; and long range—improvements which must be undertaken as future needs materialize. In addition, an estimate of cost was made for, and a definite construction priority was assigned to, all subprojects in each of the three phases. The result was an integrated master program of projects that could be activated at the proper times to keep the water and sewer systems abreast of the community needs.

Financial Study

After the recommended master program had been developed and the con-

struction costs estimated, it was possible to undertake an analysis of the city's ability to finance the proposed construction. A thorough study of past and predictable future operations of both the water and sewage systems, as well as of the amortization schedule for the several outstanding issues of water and sewer revenue bonds, was made in order to determine net revenues available after operating costs and ability to finance future improvements.

In the city under discussion, the situation was complicated by the fact that there were six outstanding prior issues of revenue bonds, two of which were noncallable. It was, of course, necessary to provide either for continued debt service to maturity on the outstanding issues or to refund the callable issues and provide for debt service on the refunding bonds, in order to ascertain what net revenues might be available for debt service on bonds issued for additional construction. It was found that combined net operating water and sewer revenues were sufficient to take care of existing debt service and provide for approximately $500,000 in new construction without an increase in existing rates; an increase in water rates to produce an additional 50 cents per month per connection, with no increase in existing sanitary sewer rates, would furnish sufficient net operating revenues for existing debt service and for new construction costing approximately $800,000.

The conclusions were that ample net revenues would be available from earnings to amortize all outstanding bonded indebtedness, to provide for the amortization of any new revenue bonds issued to finance a capital improvements program of as much as $800,000, and to finance the long-range program as self-liquidating projects after immediate and intermediate programs were paid out, releasing future earnings for debt service for additional capital improvements.

Summary and Conclusions

Having analyzed the water and sewer needs of the community, made estimates of cost, established construction priorities, and devised a method of financing the work within the capabilities of the city, it remained only to present the results of these detailed studies in the form of a rather complete summary of the entire report. The detailed findings, conclusions, and recommendations incorporated in this summary need not be quoted. The general findings will indicate the scope of the report:

Water system. In order to provide for present and future water needs of the community, an extended program of water works improvements is necessary. These improvements include:

1. Increasing the raw-water supply to insure adequate quantities of water at all times
2. Rehabilitation and modernization of the existing treatment plant to produce water in the quantities and of the quality required
3. Supplementing transmission facilities from the plant to the distribution system
4. Installation of additional elevated storage
5. Remedying the deficiencies in the existing distribution system to permit adequate flows for all domestic, commercial, industrial, and fire protection service through the installation of reinforcing mains

6. Extension of distribution lines for local service as required by the growth of the community.

Sanitary sewerage system. The present sanitary sewerage works serves only about half of the population of the community and, in the interests of public health and welfare, should be enlarged to provide service in all areas of the city. The program of extensions and improvements should include:

1. Installation of sewage collection lines in all populated, unsewered areas
2. Construction of outfall branches and enlargement of the existing main outfall to carry increased flows from newly sewered areas
3. Increased treatment plant capacity when the sewered population exceeds 6,500–7,000.

Conclusion

The author believes that the report just described was a good one, in that it defined what needed to be done, estimated the cost of doing the work, and suggested a feasible method of financing the program. As proof of the value of the report, it may be noted that substantial portions of the recommended program have been completed or are currently under construction. Three construction contracts, amounting to approximately $350,000, have been completed and four others, totaling more than $450,000, are under way. Of this $800,000 total, approximately $300,000 has been secured from federal grants.

Acknowledgment

This paper was prepared in collaboration with H. St. G. T. Carmichael Jr., an associate in J. Stephen Watkins, Cons. Engrs., Lexington, Ky.

Stationary Chlorine Storage at Tampa

By John S. Long

A contribution to the Journal by John S. Long, Supt., Water Dept., Tampa, Fla.

SINCE May 1953 liquid chlorine for use at the Tampa, Fla., water treatment plant has been received in 30-ton single-unit tank cars and transferred to a stationary storage tank, from which chlorine gas is fed to the chlorinators. Primarily, the decision to install stationary storage for chlorine was motivated by the two universal goals of water works management: uninterrupted service and economical operation. The previous system of purchasing chlorine in ton containers in multiple-unit tank car lots caused much anxiety at times when the receipt of scheduled shipments was extremely doubtful. Economy of operation is of paramount importance, because Tampa's water is inherently very difficult and expensive to treat. Preliminary investigation indicated that stationary storage would help to insure an adequate and continuous supply of chlorine and would also effect operational economies through the reduction of chemical costs.

The site selected for the installation is at the end of a city-owned railroad spur and is adjacent to the sedimentation basins, the bulk lime storage building, and the chemical storage portion of the main filter building. The chlorinators are approximately 190 ft away.

Storage Tank

In brief, the installation consists of: a storage tank mounted on a scale (Fig. 1); equipment for compressing, cleaning, and drying air; and interconnecting piping. The scale mounting was selected as the surest and simplest method of accurately determining the tank contents at any time and the amount of chlorine used each day. The pipe lever type tank scale has a net capacity of 90,000 lb and a gross capacity of 125,000 lb. It is installed in a concrete pit designed to support a building for housing the tank if that ever becomes desirable. The pit is oriented to provide the minimum required clearance for the railroad spur and to make the top of the storage tank approximately level with the top of the tank car.

Because inquiries revealed that the most readily available container for shipping liquid chlorine is the 30-ton single-unit tank car, it was decided to build the storage tank to hold 45 tons, thus leaving a margin of 15 tons to cover the time lag between ordering and receiving shipment. The actual size of the tank was based on the volume of 45 tons of liquid chlorine at 155°F, plus 20 per cent for gas space. The tank itself is built in accordance with the ASME "Code for Unfired Pressure Vessels," Paragraph U–68, from plates meeting ASME specifications SA–212, Grade B, firebox quality steel. All longitudinal and circumferential tank seams are welded by the "Unionmelt" process, and all other seams are electric-arc welded. Seams

have 95 per cent efficiency and all welds were radiographed and stress relieved. The tank has a 7-ft 1-in. inside diameter, a 38-ft overall length, a shell thickness of $\frac{47}{64}$ in. and a semi-ellipsoidal head thickness of $\frac{3}{4}$ in. It is designed for 225-psi working pressure and was subjected to a hydrostatic test pressure of 400 psi. The tank is equipped with a standard 18-in. manhole, dome, and platform arrangement, except that subway grating was substituted for the standard wood platform flooring.

The valve arrangement in the dome and the eduction pipes in the tank are identical with standard equipment on a 30-ton liquid-chlorine tank car. There is no other opening into the tank. Two steel cradle supports are attached to the tank in such a position as to match the scale girders.

The tank is not insulated, nor is it provided with a sunshade, for the reason that it is desired to feed only gaseous chlorine from it, but, as a precaution against unduly high pressures in Tampa's warm climate, the tank is finished in heat-reflective white enamel. Extending from the tank platform to the clearance line for the railroad spur is a steel catwalk on which a ladder is mounted for access to the storage tank dome. When the tank

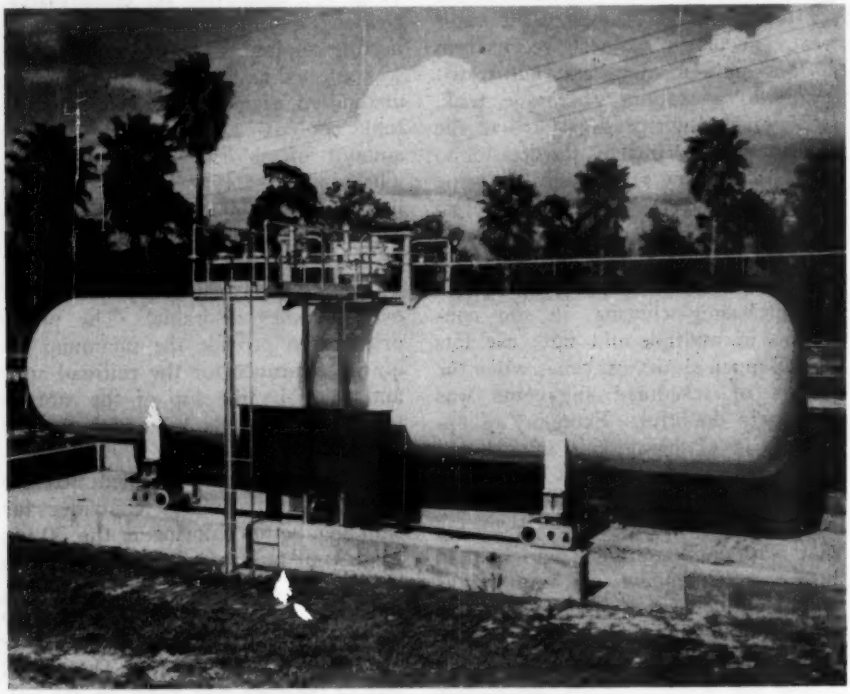

Fig. 1. Chlorine Storage Tank

The 45-ton scale-mounted storage tank is installed in a concrete pit.

car is in position, a temporary bridge is used to close the gap between the catwalk and the tank car platform.

Air Compressor and Drier

The air cleaning and drying equipment, installed in the nearby storage house, consists of an air compressor equipped with aftercooler, an oil filter, and an air drier. The compressor is a conventional two-stage type of 36-cfm piston displacement, mounted on an air receiver. The aftercooler is designed to cool the compressed air to a maximum temperature of 100°F when the maximum temperature of the cooling water is 86°F. The oil filter, placed between the air compressor and the drier, is designed to trap out any entrained vapor-stage oil coming from the compressor, because the oil might be dangerous if allowed to mix with the chlorine. The filter also removes impurities that would unnecessarily clog the desiccant in the air drier.

The drier, a one-compartment regenerative type, uses activated alumina as the desiccating agent and is capable of drying the output of the compressor to a dewpoint of minus 20°F when run continuously for not more than 8 hr. As this installation is used solely for "padding" (introducing air into) chlorine tank cars, which is an intermittent operation allowing regenerating time between cars, the single-compartment drier is satisfactory.

Piping and Valves

The pipe used throughout the system is Schedule 80 black genuine wrought iron of 1-in. nominal diameter, with screw ends made up with white lead paste joints. The fittings are of 2,000-lb W.O.G. forged steel, and the flanged unions are the standard ammonia type. The forged-steel globe valves are specially made for chlorine service. The discharge end of the air drier is permanently piped to the tank car end of the catwalk, and from this point it can easily be connected to either the storage tank or the tank car. Permanent piping is installed from each of the two liquid valves in the storage tank dome to the tank car end of the catwalk and is temporarily connected to the two liquid valves in the tank car dome for transferring liquid chlorine from tank car to storage tank.

In each of these lines is an expansion chamber and a shutoff valve. The expansion chambers guard against rupture of the connecting piping if the liquid chlorine is inadvertently trapped in the lines, and the shutoff valves are used to regulate the flow from tank car to storage tank during the unloading process. These two lines are connected with each other and with the gas line from the storage tank to the chlorinators; proper valving permits residual chlorine in the tank car and in the lines to be drawn off to the chlorinators after unloading. One gas valve in the storage tank dome is piped directly to the chlorinators. This line is connected not only to the two liquid unloading lines but also to one liquid valve in the storage tank dome, in the event that it ever becomes desirable to draw liquid from the storage tank to evaporators ahead of the chlorinators. The gas feed line, resting on supports, passes over a corner of the mixing basins and runs along the exterior of the main building, to which it is strapped, until it reaches a point outside the chlorinator room. There it goes through the wall and is connected to a pressure-reducing valve inside the room. Figure 2 is a general view of the installation.

Where the line passes over the mixing basins, a valved connection, equipped with a vacuum breaker, is connected to a perforated grid placed on the basin floor for the purpose of diffusing chlorine when it is found desirable to draw off any quantity in excess of what the chlorinator will take. Also, in this line, an expansion chamber is provided to avoid rupture from any increase in pressure. A pressure gage especially designed for chlorine service is permanently installed in the piping adjacent to the storage tank dome and always shows tank pressure, regardless of valve settings. Flexibility between storage tank, tank car, and permanent piping is provided by ball-and-socket joints with plastic gaskets.

After completion of the installation, all interconnecting piping was cleaned by flushing with carbon tetrachloride. The storage tank dome cover was removed, and the inside of the tank was thoroughly inspected, cleaned, and dried. With the dome reassembled, dry air was passed through the entire

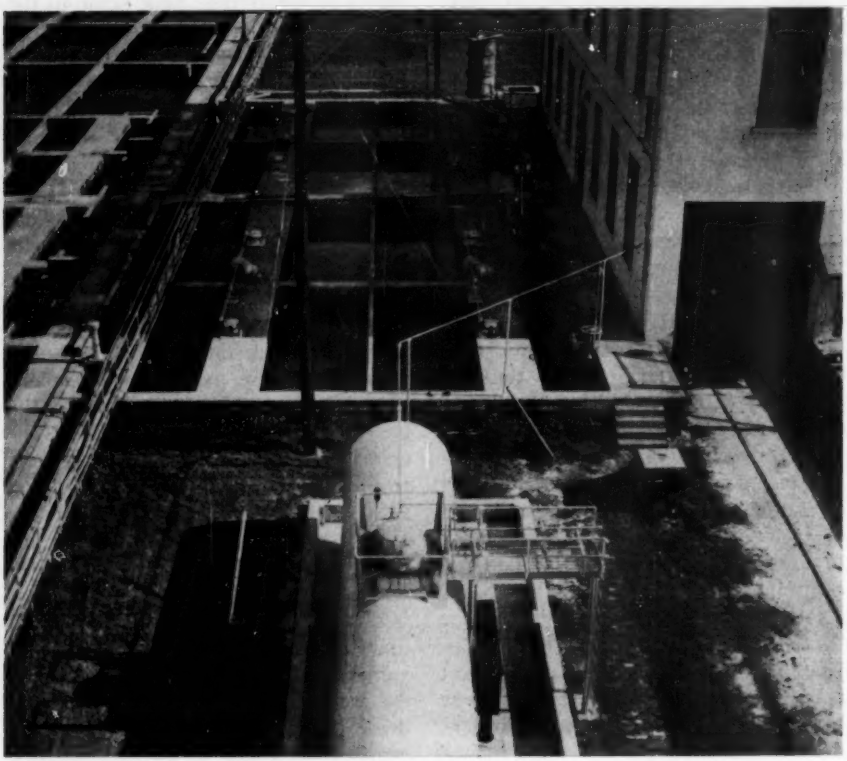

Fig. 2. General View of Installation

The gas feed line passes over a corner of the mixing basins and runs along the wall of the main building to a point outside the chlorinator room. An expansion chamber in the line can be seen on the wall in the upper right quadrant of the photograph.

system and a pressure of 150 psi was built up while leak tests were made using soapy water. The tank was then valved off, and a ton container of chlorine was connected to the pipe system, which was tested for leaks with ammonia. The tank was allowed to remain under 150-psi air pressure until the chlorine car arrived and was then exhausted.

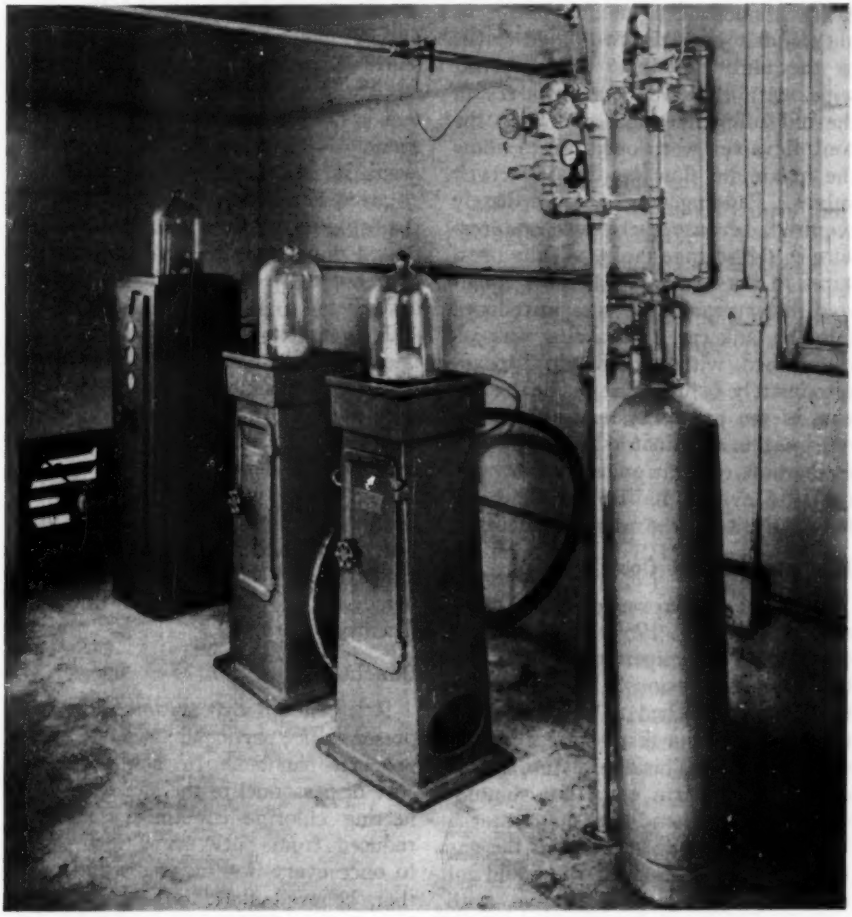

Fig. 3. Chlorinator Room

The 150-lb chlorine cylinder at right receives any reliquefied chlorine in the line.

Unloading Procedure

During unloading, the valves in the tank car dome were connected as follows: the two liquid valves to the two liquid unloading lines, one gas valve to the dry air supply, and the remaining gas valve to a pressure gage to show tank car pressure. All valve settings were checked and the two shutoff valves in the unloading lines

were closed. Extreme caution was used to admit only a small amount of chlorine into one unloading line at a time until it was certain that there were no leaks. Some leaks were detected in the flexible joints but were easily stopped by tightening the packing glands. Next the two liquid valves in the tank car dome were opened wide, with the two control valves in the unloading lines closed. Then the control valves were operated to allow the maximum flow by the ball check valves. Padding was not immediately required, because there was no pressure in the storage tank. As the pressures in the two tanks became equalized, however, dry air was introduced into the tank car. Unloading was accomplished without difficulty in approximately 6 hr. The residual chlorine in the piping system was drawn off by the chlorinators, and the air in the tank car was exhausted through the grid system in the mixing basin before the tank car was disconnected.

Precautions and Costs

Since the system was placed in operation on May 17, 1953, only one difficulty has been experienced. As has been noted previously, the chlorine feed line is attached to the outside of the building for a distance of approximately 100 ft. This line, naturally, becomes quite warm on a hot summer day and, on several occasions after a late-afternoon thunder shower, the gas in the line reliquefied. Some liquid got by the pressure-reducing valve, with the result that the orifices in the chlorinators became clogged. This difficulty was solved by connecting the feed line into a 150-lb chlorine cylinder set upright on the floor of the chlorinator room (Fig. 3). The connection to the pressure-reducing valve was teed off of the feed line above the cylinder, so that any liquid in the line now goes into the cylinder and, owing to the warmer atmosphere in the chlorinator room, is soon evaporated.

Standard safety precautions are observed in handling chlorine. Approved gas masks are kept conveniently located in strategic places, and all work in connection with the system is done by especially trained personnel. If a serious difficulty should arise, it is intended to exhaust the chlorine through the grid system in the mixing basin while feeding hydrated lime as a neutralizing agent. The water so treated can be isolated and wasted.

The overall cost of the installation is estimated at $16,000, of which $12,000 was for materials and equipment and $4,000 for construction. These figures do not include engineering fees or superintendent's wages.

The system was designed by Robert & Co. Associates of Atlanta, Ga., and was constructed by city forces. Many valuable suggestions were made by personnel of the Columbia-Southern Chemical Corp.

Conclusion

It is believed that stationary storage presents no particular hazards when properly handled. In fact, the exposure of personnel to the hazard of connecting chlorine containers has been reduced from once every few weeks to once every 3–4 months. It is further believed that the goals sought have been achieved in a more dependable supply and lower operating cost. Finally, the use of an uninsulated, unshaded tank is justified by the fact that at no time during a hot summer with a relatively full tank did the tank pressure exceed 128 psi gage.

New Commerce Department Division to Serve Water Supply Field

An announcement prepared by Thomas T. Quigley, Director of the new Water and Sewerage Industry & Utilities Div., US Dept. of Commerce, to introduce the services of his division to the field it serves. Director Quigley, who serves in that post without compensation, is on loan for these duties from Wallace & Tiernan Co., Inc., Newark, N.J.

THE Water and Sewerage Industry and Utilities Div. is one of 25 such divisions in the recently established Business and Defense Services Administration (BDSA) under the guidance of US Dept. of Commerce Secretary Sinclair Weeks in line with his program to provide, as economically as possible, essential business and defense services. These divisions are:

1. Agricultural, Construction, and Mining Equipment
2. Aluminum and Magnesium
3. Automotive
4. Building Materials and Construction
5. Business Machines and Office Equipment
6. Chemical and Rubber
7. Communications Equipment
8. Consumer Durable Goods
9. Containers and Packaging
10. Copper
11. Electrical Equipment
12. Electronics
13. Food Industries
14. Forest Products
15. General Components
16. General Industrial Equipment
17. Iron and Steel
18. Leather, Shoes, and Allied Products
19. Metalworking Equipment
20. Miscellaneous Metals and Materials
21. Power Equipment
22. Scientific, Motion Picture, and Photographic Products
23. Shipbuilding, Railroad, Ordnance, and Aircraft
24. Textiles and Clothing
25. Water and Sewage Industries and Utilities

Most of these divisions are under the direction of men on loan from industry who serve without compensation, and are staffed by government personnel experienced in their respective fields. The BDSA, which does not duplicate in any way the operation of other Commerce Dept. agencies such as the Patent Office, Weather Bureau, Civil Aeronautics Administration, or Census Bureau, is the successor agency to the National Production Authority and the Office of Domestic Commerce. It also consolidates the functions of several other offices of the department. Among its responsibilities are the continuing of those functions of NPA which are still necessary and the carrying out of certain phases of mobilization planning and preparedness studies. Additionally it provides a "home" in Washington for various segments of industry, handles many business-government problems, and, within the limits of its facilities, prepares for industry data relating to mar-

keting, operations, construction, and other phases of business activity.

The Water and Sewerage Div., operating with a small staff and modest budget, is believed adequate to provide all essential services. It is felt that the division, by being the focal point through which water and sewage problems can be viewed in proper perspective both by industry and government, can be of real value to the industry. It is *your* organization and it is here to be of assistance. Accordingly, your suggestions are welcome.

It is anticipated that this division will work extensively with other government departments, such as the Public Health Service and Geological Survey, because there is no intention to duplicate work that these agencies are now performing, to encroach upon their assigned responsibilities, or to set up any extensive fact-gathering staff within the division.

There is now available in the division files a considerable amount of data gathered over the past few years which it is thought would be useful to industry in anticipating trends and in future planning. This should provide helpful information that each segment of the industry can use as it sees fit. As the data are put into usable form, they will be made available to the segments specifically concerned. Ready now, for instance, is a tabulation of "Water Works Construction Authorized by NPA During the Period Oct. 31, 1951–Dec. 31, 1952, in Cities of 25,000 Population and Over," which will be forwarded, on request, to those interested.

The Business Outlook in the Water Works Field

The data that follow were taken from a report prepared by R. F. Boger, publisher of *Engineering News-Record*, for the Board of Governors of the Water and Sewage Works Manufacturers Assn. They give an interesting picture of the status of the water works industry in the latter part of 1953.

Contract awards for water works improvements were setting new highs in 1953. At the end of the first 46 weeks of the year, water works contracts, at $206,100,000, were 3 per cent above 1952 figures. Regionally, water works volume was running ahead of 1952 in the South (47 per cent), the Middle Atlantic region (30 per cent), the Middle West (4 per cent), and New England (17 per cent); volume was down 10 per cent in the region west of the Mississippi River and 12 per cent in the Far West.

The backlog of proposed work as of October 1953 was $1,589,000,000—5 per cent above October 1952. New projects proposed in the first 10 months of the year continued at a high rate but were down a little from estimated cost of new projects proposed in the 1952 period. For the first 10 months of 1953, the estimated cost of proposed water works projects totaled $220,000,000—5 per cent less than in 1952.

Along with the volume of business, state and municipal bonds to finance new water works construction hit new highs in 1953. The bonds (including long-term notes and certificates) sold in the first 46 weeks of 1953 for water works totaled $277,000,000—53 per cent more than in 1952. Revenue bonds for water works showed very large increases in 1953. Of the bond business noted above, 47 per cent represented revenue bonds, sales being up 119 per cent over the same period of 1952. At the end of 46 weeks, municipalities in 31 states had sold water works revenue bonds, compared with only 25 states in 1952.

Radium Content of Public Water Supplies

By John B. Hursh

A contribution to the Journal by John B. Hursh, Asst. Chief, Div. of Radiology & Biophysics, School of Medicine & Dentistry, Univ. of Rochester, Rochester, N.Y. *This paper is based on work performed under contract with the Atomic Energy Commission as part of the Univ. of Rochester Atomic Energy Project.*

THE concentration of radium * has been measured in raw and tap water samples of the public supplies of 41 cities. These measurements serve to supply information on the concentration of an important alpha-emitting natural constituent of the raw-water sources and will provide a basis for comparison with future measurements made to investigate possible contamination by radioactive wastes.

A second, equally important application of this information is in studies of the effect of the lifetime ingestion of small quantities of radium on the health and longevity of human subjects. Radium accumulates in the bony skeleton and is excreted slowly, its half-life in the body being approximately 39 years. In attempting to learn whether small amounts of radium ingested daily by a human being accumulate sufficiently to produce harmful effects, measurements were made (*1*) of the radium content of the bodies of 25 deceased persons at Rochester, N.Y. The average whole-body content of radium was found to be 1.2×10^{-10} g, approximately three orders of magnitude lower than the level (1×10^{-7} g) judged safe for workers in the radium industry. If the Rochester measurements can be judged representative, these findings lend support to the conclusion that the accumulation of naturally occurring radium from water and food does not constitute a health hazard for the population at large.

Although consideration of such residential histories as were available for the subjects tested did not reveal any trend relating geographical location with the level of radium in the body, the smallness of the sample made it desirable to find another means of testing the generality of the findings. As drinking water is an important source of ingested radium, a comparison of the tap water offered to consumers by different municipalities in the United States with the tap water of Rochester would seem to provide such a test. Such a comparison is made possible using the data reported below.

Experimental Method

Preliminary measurements made on Rochester tap water had shown that some low values of the order of 10^{-17} g radium per milliliter of water might be expected. Because the counting method used for the analysis of radium in the author's laboratory af-

* Unless otherwise specified, "radium" as used in this paper refers only to Ra^{226}.

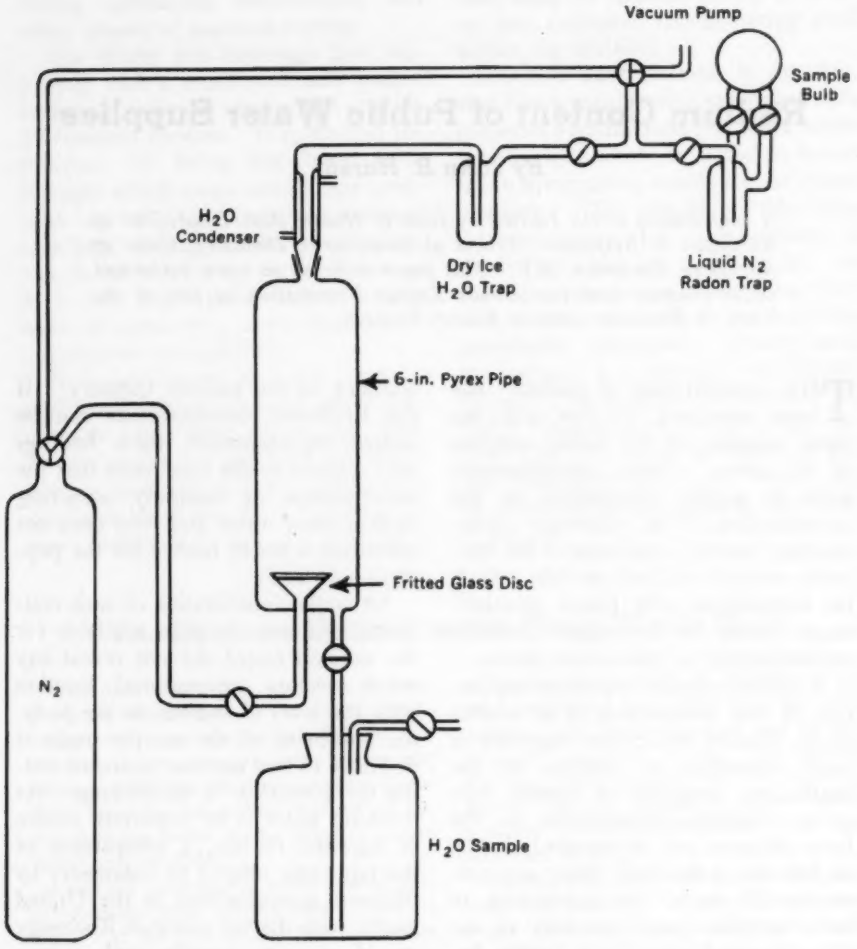

Fig. 1. De-emanation Apparatus

All connecting lines are copper or pyrex tubing.

fords approximately 3 counts per minute (cpm) per micromicrocurie ($\mu\mu$c) of radon with a background of approximately 0.2 cpm, it seemed expedient to specify a sample size that would furnish at least 0.8 cpm or approximately 0.3 $\mu\mu$c radium per sample. If the water sample were to contain 10^{-17} g radium per milliliter, the required sample volume would be 30 liters. Some compromise was made for convenience, 5-gal pyrex bottles (actually containing approximately 20 liters) being used for sample collection. Two bottles, each containing 200 ml of concentrated hydrochloric acid, were

shipped to the water departments of the cities selected, with the request that one bottle be filled with raw water from the supply source and the other with tap water furnished to the consumer. The cities were chosen primarily on the basis of population, with some attention to geographical coverage. Altogether, the 41 cities serve approximately 20 per cent of the population of the United States.

When the bottles were received at the laboratory, any suspended matter in the water was allowed to settle. The clear supernatant was de-emanated, as described below; any sediment in the bottle was discarded; and the sample was returned to the bottle. A measured amount of boiled, double-distilled water was added to fill the bottles completely, and they were sealed and set aside to collect emanation.

As the laboratory equipment for removing the radon from a radium solution would accommodate a maximum sample size of approximately 200 ml, it was necessary either to devise a new apparatus to handle volumes of 20 liters or to boil the sample down to the smaller volume, a procedure regarded as inconvenient and conducive to potential loss of the radium content. The apparatus that was assembled is schematically represented in Fig. 1. All conduction lines were either pyrex or copper tubing. At the end of a radon collection period of 3 weeks or more, the bottle was connected to the apparatus as shown in Fig. 1. The system was evacuated by pumping for at least half an hour and then filled with tank nitrogen. Next, the water sample was forced up into the pyrex column and the radon was swept for 1½ hr with a stream of small bubbles of tank nitrogen evolving from a fritted disk at a rate of 1 cu ft per hour. A trap cooled by an acetone–solid CO_2 mixture was used to catch the water vapor. The radon was frozen out in a liquid-nitrogen trap. At the conclusion of the run, the trap was warmed and the radon was flushed with tank nitrogen into an evacuated 1-liter collecting glass bulb. The radon was then transferred by water displacement, passing through a water vapor trap and into the counting chamber. The counting equipment, which has previously been described in detail (*1*), consists of a 2-liter brass chamber run as an alpha ionization counter, followed by a preamplifier, an amplifier, a discriminator, and a Streeter-Amet recorder. Samples were counted for 15 hr or longer.

TABLE 1

Recovery of Radon From Control Solutions

Measured Radon *μμc*	Calculated Radon *μμc*	Recovery *per cent*
8.08	8.18	98.8
8.90	8.78	101.3
7.38	7.99	92.4
3.58	3.67	97.5
8.30	8.14	102.0
4.06	4.00	101.5
4.73	4.42	107.0
9.34	9.00	103.8
8.48	8.97	94.7
	Avg	99.9

Control Experiments

Measurement of radon in blanks. Distilled water from the laboratory supply was redistilled in an all-pyrex glass still and used to fill four 5-gal pyrex bottles to which 200 ml of con-

centrated hydrochloric acid had been previously added. Any radon present was removed from this water by de-emanating in the glass tower. After the sample had been returned to the bottle, it was sealed and set aside for 3 weeks or more. It was then analyzed for radon according to the method described above. The results of thirteen such analyses gave an average value of 0.25 $\mu\mu$c radon with an associated standard deviation of $\pm$ 0.02 $\mu\mu$c. Because the origin of the radon measured in the blank was uncertain, the average value of 0.25 $\mu\mu$c was arbitrarily subtracted from all the radon measurements of the experimental water samples before calculation of the equivalent radium values.

Recovery runs. Two 5-gal pyrex bottles were filled with double-distilled water plus 200 ml of concentrated hydrochloric acid. To one bottle, 5 $\mu\mu$c of radium in solution was added; and to the other, 10 $\mu\mu$c. These samples were de-emanated and allowed to collect radon. Radon collection and measurement were carried out in the same way as described above for the experimental samples. The results of these measurements, listed in Table 1, show a satisfactory recovery of the expected amounts of radon.

Absolute accuracy of radium measurements. Interlaboratory checks on the same water sample (Omaha, Neb., raw water) were made with the cooperation of the Massachusetts Institute of Technology. Another set of water samples (Joliet, Ill., raw and tap water) was checked by the Argonne Lab. It is gratifying to state that the results showed a maximum spread of only 20 per cent, which, considering the nature of the analysis, is regarded as adequate agreement.

Results and Discussion

Two or more analyses were made of each water sample, the average value being listed in Table 2. The individual determinations are mostly within 10 per cent of the average values, with greater variation encountered as the samples approached levels of 0.1×10^{-16} g radium per milliliter. This increased variation is explained by the fact that, at the level mentioned, the sum of the blank correction plus the counting background is approximately twice as high as the counts from the radium in the sample.

Raw Water

The interpretation of the raw-water results is subject to an important limitation that should be explicitly stated at the outset. Although the results on the majority of the water samples are estimated to be accurate within approximately 10 per cent, it may by no means be inferred that the average value of the radium content of the individual raw-water source has been established within this range. Water chemists are well aware of the seasonal, as well as the day-to-day, variations in the concentration of dissolved solids in streams and rivers. The discharge of a stream is dependent on precipitation. As runoff water characteristically has a relatively low concentration of dissolved salts, the usual finding is that the salt concentration is lower at times of high water. The magnitude of the seasonal change will vary, of course, depending on the particular stream or river in question. Measurements reported (*3*) for the West Branch of the Susquehanna River during the period October 1944–September 1945 showed a dissolved-solids content ranging from a mini-

mum of 53 ppm in March to a peak of 219 ppm in early October. A similar seasonal variation in the concentration of radium may be inferred. This effect will be most noticeable in river supplies and will probably be less significant in supplies derived from large lakes or deep wells. A second important consideration is whether the raw-water sample is representative of the body of water at the sampling time. For instance, it is known (*3*) that the concentration of dissolved solids in rivers varies with the distance from the river bank. For the authenticity of the samples in this respect, the author has relied on the experience of the water works officials supervising sample collection.

Despite the uncertainty produced by the single-spot sampling procedure, it is noteworthy that the data meet several tests of internal consistency. For example, the Mississippi River, as sampled at St. Louis, shows a relative radium content of 10.8; after dilution by mixing with the Ohio River—measured at Cincinnati as 0.61 and at Louisville as 0.84—the Mississippi at New Orleans yields a relative radium content of 4.25. If it is assumed that raw waters very low in dissolved salts contain a high proportion of runoff or are collected from areas underlain by comparatively insoluble rocks, a low radium concentration would generally be expected. Among the supplies sampled, Atlanta, Baltimore, Boston, New York (Catskill and Croton supplies), Portland, and Tacoma are unusually low in dissolved salts (*2*), and, correspondingly, the radium concentrations of all these samples were equal to or less than 0.20×10^{-16} g radium per milliliter. The raw water of Charleston, S.C., is a notable exception because, although it has a low salt content, the radium concentration is 1.81×10^{-16} g per milliliter. It appears unlikely that this deviation can be explained solely in terms of seasonal variation. The other samplings of the Piedmont Plateau–Coastal Plains region (the Chattahoochee at Atlanta, Ga.; the Cahaba at Birmingham, Ala.; Walnut Creek at Raleigh, N.C.; and the James River at Richmond, Va.) all show radium concentrations less than one-fifth of the value for the Edisto River at Charleston. The converse situation—that is, low radium values and high dissolved-salt content—is encountered in the raw water used by the California cities of Los Angeles, Sacramento, and San Francisco. The Los Angeles water, for example, has a total dissolved-salt content of 302 ppm, whereas the measured radium is only 0.08×10^{-16} g per milliliter. Speculations about the possible cause of these anomalies would enter the realm of geochemistry and should in any event be deferred until the radium determinations are supported by adequate multiple sampling.

Because the chemical nature of the waters of the Great Lakes remains fairly uniform throughout the year, the four radium measurements made on this system may be scrutinized more closely. As set forth in Table 2, Lake Michigan at Chicago measures 0.24 units, the Detroit River at Detroit measures 0.26, Lake Erie at Cleveland 0.33, and Lake Erie at Buffalo 0.35. The data are consistent in that no large differences are found and the two measurements on Lake Erie are in agreement within the limits of accuracy of the method. As a consequence of the significant increase in the radium concentration of Lake Erie

TABLE 2

Radium Analysis of Raw and Tap Water Samples

City	Source	Sampling Date	Treatment Method*	Radium per Milliliter H_2O 10^{-12}-g units	
				Raw Water	Tap Water
Atlanta, Ga.	Chattahoochee R.	5–21–51	A†	0.17	0.09
Baltimore, Md.	Gunpowder R.	7–16–51	A	0.20	0.08
Birmingham, Ala.	Cahaba R.–Lake Purdy	5–22–51	A	0.24	0.17
Bismark, N.D.	Missouri R.	5–4–50	A	2.43	0.26
Boise, Idaho	Shallow & deep wells	5–5–50	B†	1.03	0.96
Boston, Mass.	Nashua R.	7–18–51	B	0.14	0.17
Buffalo, N.Y.	Lake Erie	5–4–51	A	0.35	0.28
Charleston, S.C.	Edisto R.	5–9–51	A†	1.81	1.41
Charleston, W.Va.	Elk R.	7–19–51	A	0.41	0.45
Cheyenne, Wyo.	Surface and wells	8–28–51	A†	0.50	0.34
Chicago, Ill.	Lake Michigan	7–10–50	A†	0.24	0.29
Cincinnati, Ohio	Ohio R.	5–21–51	A	0.61	0.33
Cleveland, Ohio	Lake Erie	5–31–51	A	0.33	0.23
Dallas, Tex.	Lakes Garza & Bachman	7–19–50	A	0.85	0.32
Denver, Colo.	S. Platte R.	5–4–50	A	0.77	0.47
Detroit, Mich.	Detroit R.	5–9–51	A†	0.26	0.18
Indianapolis, Ind.	Fall Creek & White R.	5–8–51	A	1.37	0.86
Joliet, Ill.	Deep wells	4–22–52	B	65.4	57.9
LaVerne, Calif.	Colorado R.	4–29–52	A	1.00	0.35
Los Angeles, Calif.	Owens Valley Aqueduct	5–5–50	B	0.09	0.08
Louisville, Ky.	Ohio R.	5–18–51	A	0.84	0.41
Miami, Fla.	Shallow wells	8–24–51	A	4.78	1.68
Memphis, Tenn.	Shallow & deep wells	7–10–50	A	2.11	1.70
New Orleans, La.	Mississippi R.	5–24–51	A	4.25	0.16
New York, N.Y.	Catskill supply	7–27–51	B	0.15	0.18
New York, N.Y.	Croton supply	7–27–51	B	0.20	0.18
Oklahoma City, Okla.	N. Canadian R.	7–12–50	A†	1.06	0.42
Omaha, Neb.	Missouri R.	7–13–50	A	17.7	0.54
Philadelphia, Pa.	Delaware R.	7–14–51	A	0.48	0.44
Phoenix, Ariz.	Shallow wells along Verdi R.	6–20–50	B	0.27	0.18
Pierre, S.D.	Shallow wells along Missouri R.	7–14–50	B	0.62	0.15
Pittsburgh, Pa.	Allegheny R.	2–17–50	A	37.0	1.41
Portland, Ore.	Bull Run R.	5–9–50	B	0.14	0.01
Raleigh, N.C.	Walnut Creek	7–26–51	A	0.22	0.25
Richmond, Va.	James R.	7–17–51	A	0.33	0.23
Sacramento, Calif.	Sacramento R.	5–8–50	A	0.18	0.15
Salt Lake City, Utah	Cottonwood Creek	5–6–50	B	0.34	0.50
San Francisco, Calif.	Calaveras Res.	5–19–50	B	0.18	0.07
St. Louis, Mo.	Mississippi R.	7–19–50	A	10.8	0.28
Tacoma, Wash.	Green R.	5–21–50	B	0.02	0.00
Washington, D.C.	Potomac R.	8–30–51	A	0.33	0.27
Wichita, Kan.	Deep wells	7–18–50	A	2.27	0.75

* Key: A—flocculation, settling, and filtration; B—simple chlorination only or no treatment. Unless otherwise noted, this information was supplied to the author by the water department concerned.

† Geological Survey data (*2*).

water, it may be inferred that streams such as the Maumee River carry water with a concentration of radium several times 0.26 units into Lake Erie.

The highest radium content among the surface waters tested was found for the sample of Allegheny River water at Pittsburgh. As this river drains a coal mine and oil well region, this high value may be due in part to discharge of mine water and connate water from oil wells into the Allegheny River. Botset (*4*) found radium concentrations in connate waters from oil wells as high as 1.7×10^{-12} g per milliliter.

Considering the data as a whole, it will be seen that the sampling includes 5 ground water sources; 2 supplies consisting of shallow wells along river banks; 1 mixed ground and surface supply; 25 streams (some of which are impounded in large reservoirs); 5 lake sources; and 4 reservoirs. The five ground sources contain 1–65 units of radium, whereas the surface sources range from 0 to 37 units. The average, as well as the median, value is higher for the ground sources than for the surface sources. If the very high radium content of the Joliet, Ill., well water is excluded, the median radium content remains six times as high for the ground water as for the surface water, but the average concentration for ground water (2.5 units) is not significantly different from that for surface water (2.1 units). The general conclusion that ground water sources usually may be expected to contain a higher concentration of radium than surface sources is subject to the reservation that only five ground sources were sampled.

Tap Water

The tap water measurements, with the exception of Joliet, range from 0.0 to 1.7×10^{-16} g of radium per milliliter. Twenty-six cities (including 75 per cent of the total population of the cities sampled) use water with a concentration lower than 0.36 units and 15 cities use water with a concentration higher than 0.36 units, the average value for Rochester tap water as determined in the author's laboratory. It may be concluded that the radium concentration in Rochester water is roughly representative of the radium concentration in water supplies serving one-fifth of the population of the United States.

The tap water supply of Joliet, excluded above, is truly exceptional, its radium concentration being 57.9 units. It will require further measurement of ground waters, particularly of well water made potable by simple chlorination, in order to decide how large a group of people drink water with a radium content at the Joliet level. Although it might be conjectured that this group is a small one, it should be pointed out that the sampling used in this study, inasmuch as it was confined to large urban populations, tended to neglect the smaller communities and, consequently, the ground water sources. It is estimated (*2*) that ground water furnishes the domestic supply of approximately half the population of the United States. Four of the five ground water supplies sampled gave radium concentrations of 1 unit or more. It is therefore likely that, if the water supplies of the entire United States were taken into account, the average radium concentration would be found to be somewhat higher than that reported in the present study.

Radium Content in Body

The finding that Rochester tap water is roughly representative of the water consumed by the urban popula-

tion centers sampled has the corollary that, if the content of radium in the body is proportional to that in the ingested water, the Rochester whole-body measurements are roughly representative of this population group. The assumption that the radium stored in the body is proportional to that in water brings into question the relative importance of food as a radium source. As a reasonable fraction of the food consumed in a particular locality may have been grown in another part of the country, the stipulation of food as a major radium source carries with it the likelihood that geographical differences in radium intake would be more or less smoothed over. Pending the availability of data on the radium concentration in food and the intestinal absorption of food radium, the analysis of drinking water is the only method of approximating differences in radium intake. The method receives some limited qualitative support from published data describing measurements made in two laboratories outside the United States. Sievert (*5*) reports gamma measurements on living subjects leading to the conclusion that a 50-year-old man residing in Stockholm, Sweden, has an average body content of 80×10^{-10} g radium. On the assumption that tap water (and food water with an equal radium concentration) accounts for total radium intake and that 2 per cent of the ingested radium is retained by the body, Sievert, using the method of calculation employed by Hursh and Gates (*1*), estimates that his body content values are compatible with a tap water concentration of 10 to 20×10^{-15} g radium per milliliter. He asserts this to be a reasonable value for Swedish conditions. Krebs (*6*) has measured the radium content of deceased individuals who lived in various regions of Germany, and he reports an average body content of 1.4×10^{-8} g radium equivalent. On the occasion of a visit to the Rochester laboratory in 1949, Krebs stated that the radium content of the water ingested by his German subjects was in all likelihood much higher than that of Rochester water and that, in fact, measurements made by Krebs and others on the water of Frankfurt, Germany, gave results of 3 to 5×10^{-12} g radium per milliliter.

These reports are satisfactory to the extent that higher contents of radium in the body are associated with the reasonable presumption of higher radium concentrations in tap water, but they are of questionable value in the calculation of the quantitative relation between the two parameters. Such a calculation made for the Rochester measurements indicates that the average ratio of radium per gram wet weight human skeleton (70-year-old individual) to radium per milliliter Rochester tap water is $1.76 \times 10^{-14} : 0.36 \times 10^{-16} = 490 : 1$.

TABLE 3

Comparison of Activities of Rn^{222} and Ra^{226}

Spring No.	Activity—10^{-16} c*/ml	
	Rn^{222}	Ra^{226}
1	362	2.6
2	2,970	1.3
3	6,200	1.4
4	2,695	1.3

* Curies.

Other Alpha Emitters

In the experiments described, only radium (Ra^{226}) has been measured.

The problem of assessing the importance of the other 24 naturally occurring alpha emitters may be simplified somewhat by: [1] neglecting the contribution of the actinium series, which, at best, would furnish a total activity concentration equal to approximately 5 per cent of the activity concentration from the U^{238} series*; and [2] assigning an activity to the very short half-life alpha emitters equal to the activity of their long-lived immediate predecessor.† Nevertheless, it remains a formidable task to analyze water samples for the remaining alpha particle members of the uranium and thorium series. The simple practice of measuring a single, long-lived member of each series and assuming that the remaining members exist in approximate radioactive equilibrium in the water sample can be shown to be invalid both theoretically and experimentally. Because each series contains an isotope of radon, which is a gas moderately soluble in water, and because the various member elements differ in their tendencies to form colloids, to adsorb on particles, or, conversely, to form soluble complexes, it would be indeed surprising to find such equilibrium conditions existing in raw-water samples. Experimental evidence for disequilibrium between Ra^{226} and its daughter, Rn^{222}, in spring water samples taken near Rochester is cited in Table 3.

Significance to Health

For the water plant chemist who, anticipating an increase in the concentration of radioactive material in his water supply as a result either of radioactive wastes or of fission products, seeks to establish the background radioactive level, a knowledge of the precise transient radioactive character of the raw water is not only insufficient but unnecessarily detailed as well. His interest must focus on those radioactive components which are, biologically speaking, important potential hazards. In addition to the concentration of a particular emitter in the tap water, criteria such as absorption into the body, localization in a particular tissue or organ, rate of excretion, physical half-life, and presence of short-lived daughters become the determining factors in deciding the question of which alpha emitters should be measured. A tentative assessment of the potentially important emitters may be made by considering the pertinent biological and physical properties of the members of the uranium and thorium series. To aid in following the argument, a chart giving half-lives and interrelations is shown in Fig. 2.

In any natural sample, U^{238} and U^{234} will occur in fixed proportions. These isotopes do not have any immediate short-lived daughters that must be considered in evaluating their toxicity in the body. On the other hand, Ra^{226}, when fixed in the body, determines the body content of three short-lived alpha-emitting daughter products. As approximately half of the Rn^{222} formed

* The justification for neglecting the actinium family rests on the fact that the ratio of the activity per gram of the earth's crust for U^{235} (head of the actinium series) and U^{238} (head of the uranium series) is 1:20. As the heads of the two series are chemically identical, it is expected that their geological distribution and chemical solubility would be the same. For the most part, the same elements are duplicated as daughter products in each of the two series.

† By reference to Fig. 2, it can be seen that the activity of Po^{218} will be equal to the activity of Rn^{222}; Rn^{220} and Po^{216} will be governed by the activity of Ra^{224}; and Po^{212} will be governed by Bi^{212}.

in the body escapes in the breath, each pair of alpha particles released by Ra^{226} is accompanied by a total of three additional alpha particles from the daughters.

Owing to the nature of the thorium decay series, it is not so simple to select the particular element that governs the activity of the short-lived thorium daughters in the body. It is a question whether the Th^{232}–Th^{228} combination (existing in radioactive equilibrium) would determine the daughter-product level by building up Ra^{228} to an equilibrium level in the course of time, or whether the relatively long-lived beta-emitting Ra^{228} ingested from the water would constitute the principal source of the dependent daughter products and would build up Th^{228} to an activity concentration compatible with the Ra^{228} body content. Which of these alternatives might operate in a given situation would depend on the relative activity concentration of Th^{232} and Ra^{228} in the water sample under consideration. The calculation in Table 4 has been made for each element as if its concentration served to control the daughter-product level. As the daughter products were assumed to be in equilibrium

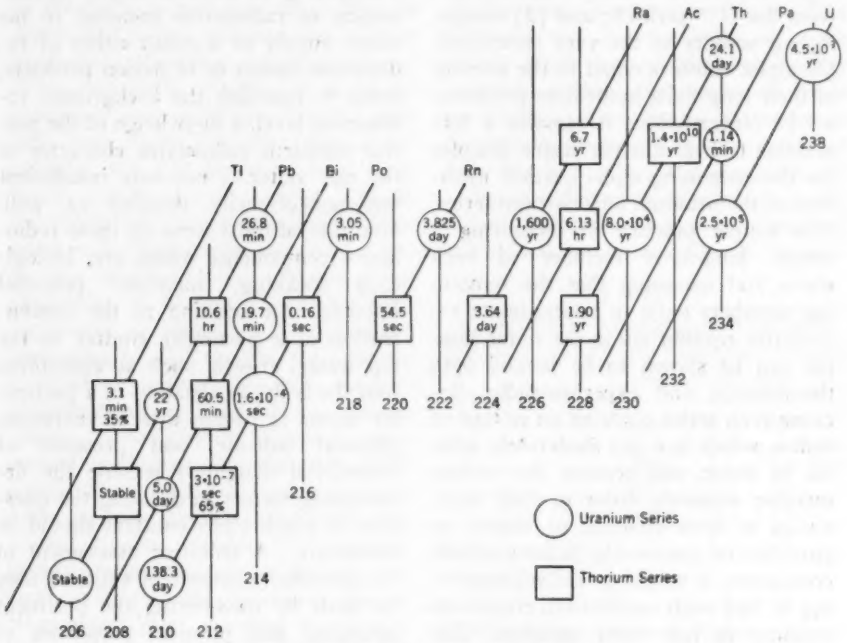

Fig. 2. Uranium and Thorium Series

Relationships and half-lives of the principal naturally occurring members of the uranium and thorium series are shown. To follow the decay scheme, move from right to left for the decay of an alpha particle emitter and at right angles downward for a beta particle emitter.

amounts with reference to Th^{232} and Ra^{228}, respectively, and as, in each instance, a number of long-lived intermediate elements must be built up in the body before equilibrium conditions are attained, the calculation in Table 4 is an overestimate of the potential "toxicity" of Th^{232} and Ra^{228}. The remaining two long-lived elements, Po^{210} and Th^{230}, having no short-lived daughters, may be expected to play a minor role.

Table 4 makes an attempt to compare the toxicities of the various key isotopes in the light of such biological information as is available. The last column of the table lists the concentration of the element in water which, if ingested chronically, would lead to about the same rate of radiation energy release in the body. For the purposes of this qualitative estimate, no account has been taken of a possibly unequal distribution of the element in the body or of the differences in radiation sensitivity of various organs.

To the degree that the biological factors are correct, the calculation serves two purposes: [1] it demonstrates the relative importance of Ra^{226}, as opposed to other alpha-emitting isotopes present naturally in water sources; and [2] it emphasizes the inadequacy of total alpha activity as a measure, in itself, of the potential hazard of radioactivity in drinking water.

It should be noted that these considerations refer only to naturally occurring radioactive elements. If the contaminants involved were uranium mining or milling wastes or fission products, the problem would have to be reconsidered.

TABLE 4

Naturally Occurring Alpha Emitters as Potential Health Hazards *

Element	Effective Energy per Emission† *mev*	Per Cent Dose Retained‡	Effective Half-Life§ *days*	Relative Toxicity‖	Equivalent Relative Concentration#
Ra^{226}	14.5	1.5	1.6×10^4	3.48×10^5	1
U^{238}	8.9	0.01	3×10^9	2.67×10^5	1,300
Th^{232}**	35.3	0.039	4.3×10^4	5.87×10^4	5.9
Ra^{228}**	31.1	1.5	2.08×10^3	9.66×10^4	3.6
Th^{230}	4.7	0.039	4.3×10^4	7.88×10^3	44.2
Po^{210}	5.3	4	40	8.4×10^3	414

* All biological constants have been taken from National Bureau of Standards (7).

† The value listed is the sum of the energy (in million electron volts) of the principal emitter plus that of the dependent short-lived daughter products.

‡ That part of the dose which becomes established in the body tissues and is excreted at a rate proportional to the body content.

§ The value listed takes into account loss by excretion and by physical decay.

‖ The product of the values in the preceding three columns of the table.

The relative concentration (activity units per unit volume) in water, which, if ingested chronically, would lead to the release of comparable amounts of ionizing energy in the body.

** Element named is assumed to determine the body content of the short-lived daughters of the thorium series. If, for reasons of solubility in the water source or other natural causes, the activity concentration of either Th^{232} or Ra^{228} were greatly in excess of the other, the one with higher activity would presumably control the daughter-product level.

Acknowledgment

The author wishes to express his appreciation to the personnel of the water departments solicited, for their wholehearted cooperation in this project. He is also indebted to R. D. Evans of the Massachusetts Institute

of Technology and to L. D. Marinelli and A. F. Stehney of the Argonne Lab. for their assistance in checking the accuracy of the radium measurements.

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Survey Meters and Electroscopes for Monitoring Radioactivity in Water

By William J. Lacy and Bernd Kahn

A contribution to the Journal by William J. Lacy, Chemist, San. Engr. Branch, Engr. Research & Development Labs., Ft. Belvoir, Va. (assigned to Oak Ridge National Lab., Oak Ridge, Tenn.), and Bernd Kahn, Assoc. Health Physicist, Oak Ridge National Lab., Oak Ridge, Tenn.

IN certain circumstances, water supplies may contain appreciable amounts of radioisotopes originating in industries, hospitals, and research laboratories, or resulting from the use of nuclear weapons. The residual contamination in the water after treatment should not exceed maximum permissible concentration values. Suggested emergency permissible concentration values for mixed fission products during the period immediately following a nuclear explosion are given in Table 1, and some peacetime maximum permissible concentration values are given in Table 2. Whatever the source of the contamination, the amount of radioactivity present should be determined, so that the hazard may be assessed. A variety of radiation detection instruments exist, but, for field or emergency conditions, instruments that are simple, portable, and readily available commercially are necessary. Electroscopes and Geiger-Muller survey meters meet these requirements. The purpose of the studies discussed in this paper was the evaluation of methods for the measurement of radioactive contamination in water.

Three commercially available thin-walled Geiger-Muller type beta-gamma survey meters were used for test purposes: [1] Nuclear Corp.,* Model 2610A; [2] Tracerlab,† AEC Model XSGM-19; and [3] El-Tronic,‡ Model PR3. These instruments read in milliroentgens (mr) per hour. In establishing conversion factors between these units and microcuries (μc) per milliliter, readings on the instruments were taken in two ways: with the tube either above or submerged in a sample containing a known concentration of radioactive material.

The survey meters were calibrated with a radium gamma source. The probes of the three instruments differ. The six different radioisotopes used to obtain the data reported are among those listed in Table 3. The radioisotopes were obtained from the operations division of the Oak Ridge, Tenn., National Lab., and the concentrations in microcuries per milliliter were determined by that division. The desired levels of activity were obtained by diluting the isotope solutions with tap water.

The radioactive isotopes studied included some with energies above and

* Nuclear Instrument & Chem. Corp., Chicago.

† Tracerlab, Inc., Boston, Mass.

‡ El-Tronics, Inc., Philadelphia.

some with energies below 0.95 million electron volts (mev), which is the approximate average maximum beta energy of a U^{235} fission products mixture 4–28 days old (*2*). The concentrations investigated ranged from 10^{-4} to 10^{-1} μc per milliliter, thereby including the emergency permissible concentration values.

Measurements on the sample were made in two ways with each instrument: [1] the unshielded probe was supported on the rim of a 3¾-in. diameter plastic dish containing 175 ml of the diluted isotope, the sensitive part of the tube being above the center of the dish; and [2] the unshielded probe, protected against contamination by a very thin rubber sheath, was submerged at the center of a glass beaker containing 1,000 ml of solution being tested. These test methods are illustrated in Fig. 1. Identical procedures were used with all instruments.

Results and Discussion

With the probe submerged in a given sample, the readings of all instruments were greater than the readings taken above the dish containing the same sample (Fig. 2). There are two important reasons for the greater sensitivity of the first method: [1] the radiation is emitted by the solution in all directions and the entire surface of the submerged tube is surrounded by the solution, while, if the probe is held over the liquid, only about half of its surface is exposed to radiation; and [2] the range of beta particles is short, and the air space above the water removes some of the beta particles of lower energy.

The gamma readings are much lower than the beta readings because of the low efficiency of Geiger-Muller tubes for gamma rays (0.5–5 per cent), and the small volume of water (approxi-

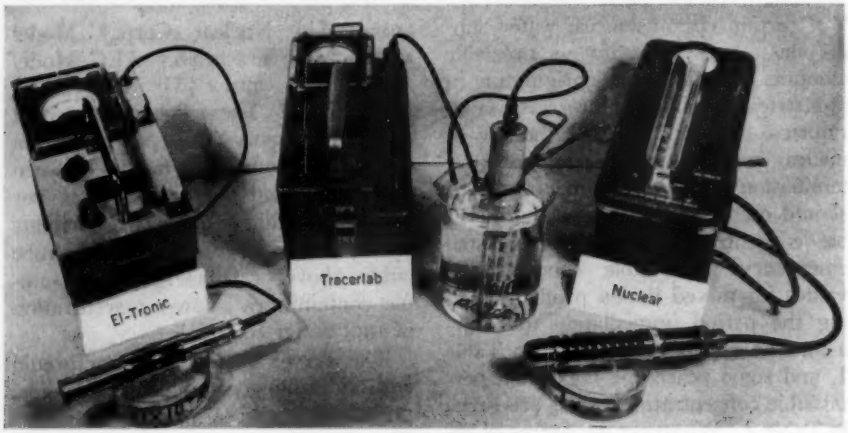

Fig. 1. Survey Meters

The three thin-walled Geiger-Muller type beta-gamma survey meters shown above were used in this study.

mately 3 in. thick) around the tube.

Beta particles from a particular isotope have a characteristic energy distribution ranging from zero to some maximum value. The average beta energy from a radioisotope is approximately one-third the maximum energy, the exact ratio depending on the atomic number of the radioisotope.

According to K. Z. Morgan (unpublished), the range of beta particles, in

TABLE 1

Emergency Permissible Levels for Radioactivity in Drinking Water for Period Immediately Following Nuclear Explosion *

Period of Consumption *days*	Beta-Gamma Activity *μc/ml*	Alpha Activity *μc/ml*
	Acceptable	
10	9×10^{-3}	5×10^{-3}
30	3×10^{-3}	1.7×10^{-3}
	Safe	
10	3.5×10^{-3}	2.0×10^{-4}
30	1.1×10^{-3}	6.7×10^{-5}

* From Bale (*1*).

centimeters, is given by the equation:

$$S_\beta = \frac{1}{\rho}\left[0.54\, E_{max} - 0.13(1 - e^{-3.2\, E_{max}})\right]$$

in which ρ is density; E_{max} is energy, in million electron volts; and e is the natural-logarithm base.

A close approximation for the range of beta particles whose maximum energy is greater than 0.8 mev is given by the equation:

$$S_\beta = \frac{1}{\rho}\left[0.542\, E_{max} - 0.133\right]$$

This equation is based on the work of L. E. Glendenin and C. D. Coryell (*3*).

From these equations, it can be seen that, for beta particles, 2 cm of water around the tube would be equivalent to an infinite thickness.

The survey meter readings for all samples gave essentially straight lines when radiation was plotted against concentration on logarithmic paper (Fig. 3). The readings with the three

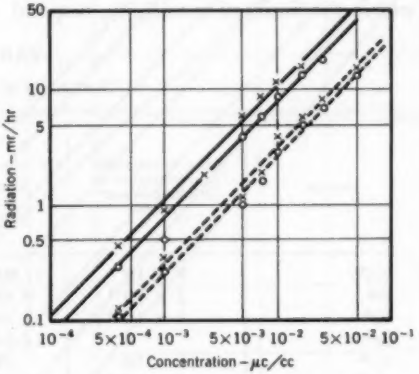

Fig. 2. Effect of Location of Probe

Key: solid lines—probe submerged; broken lines—probe above dish; ×—Tracerlab meter; ○—Nuclear Corp. meter. The beta source was Ba^{140}-La^{140}. The same sample was used for all observations in this test.

meters on the same sample were consistent. Owing to the lower maximum energy of their beta particles, Tl^{204} and I^{131} gave lower meter readings than other radioisotopes. The distance the probe is held from the sample greatly influences the radiation reading. In a submerged reading, this is not a variable factor. From the results plotted in Fig. 3, it can be seen that the data obtained with the two fission product

mixtures compared very closely to the readings obtained with P^{32}.

Figure 4 is a graph comparing the results obtained by the authors with those reported by Hursh and others (*4*). All the readings shown in Fig. 4 were obtained on fission product mixtures with the probe held over a dish.

Conclusions

It was found that survey meters, within the limits of sensitivity, respond directly to variations in the concentration of activity in water. Therefore, a sample of unknown concentration can be monitored in terms of milliroentgens per hour. The reading may be converted by means of a graph to approximate the concentration of activity in microcuries per cubic centimeter. It can then be determined whether the concentration is within the emergency permissible range given in Table 1. The meter readings on any sample are affected by: [1] the radioisotope present, [2] the distance of the detector from the surface of the liquid, [3] the volume of the sample, and [4] the shape and material of the dish or container.

The meters should be calibrated with a known standard to read a given value in milliroentgens per hour at a given distance from the source. Hursh and colleagues (*4*) suggest a calibration source using uranium oxide and Ward's bioplastic spread evenly over the inside flat surface of a small lid. This gives a handy, tough, and convenient standard.

Calibrations based on Ru^{106}-Rh^{106} solutions of known concentration will give higher readings than a fission

TABLE 2

Sensitivity of Electroscope *

Isotope	Max. Permissible Concentration in Drinking Water† $\mu c/ml$	*R* Values‡		
		Evaporated Sample $\frac{div/hr}{\mu c}$	10-ml Sample $\frac{div/hr}{\mu c/ml}$	150-ml Sample $\frac{div/hr}{\mu c/ml}$
Na^{24}	8×10^{-3}	11,000	13,000	50,600
P^{32}	2×10^{-4}	9,500	16,600	43,000
K^{42}	1×10^{-2}	7,340	27,800	93,000
Sc^{46}		14,200	3,820	14,700
Cr^{51}	5×10^{-1}	100		440
Co^{60}	2×10^{-2}	14,200	3,800	17,800
$Sr^{90} + Y^{90}$	8×10^{-7}	24,300	25,000	74,400
Y^{90}		8,300	21,500	63,200
Nb^{95}		12,000	1,250	5,760
$Ru^{106} + Rh^{106}$		9,180	29,600	93,800
I^{131}	3×10^{-6}	15,500	5,580	14,800
Au^{198}	3×10^{-3}	14,900	8,320	25,600
Tl^{204}		14,800	5,510	16,900
Pu^{239}	1.5×10^{-6}	1.85×10^{6}		1.5×10^{6}

* Landsverk Model L–75.
† National Committee on Radiation Protection (*5*).
‡ See page 61.

product mixture. Calibrations based on Tl^{204} solutions will give a lower meter reading. It is advisable to use these two values as limits when measuring a fission product mixture. With P^{32} as a comparator, the results would be closer to the true level of activity.

The most accurate meter readings are the midscale values. Therefore, if a scale of twenty is being used, the readings between eight and twelve are more accurate than the ones outside this range. If the readings from any particular sample fall at either extreme of the scale, they may be brought to the midscale range by diluting the sample. This procedure is not feasible if uncontaminated water is not available for dilution purposes or if the original reading is close to background.

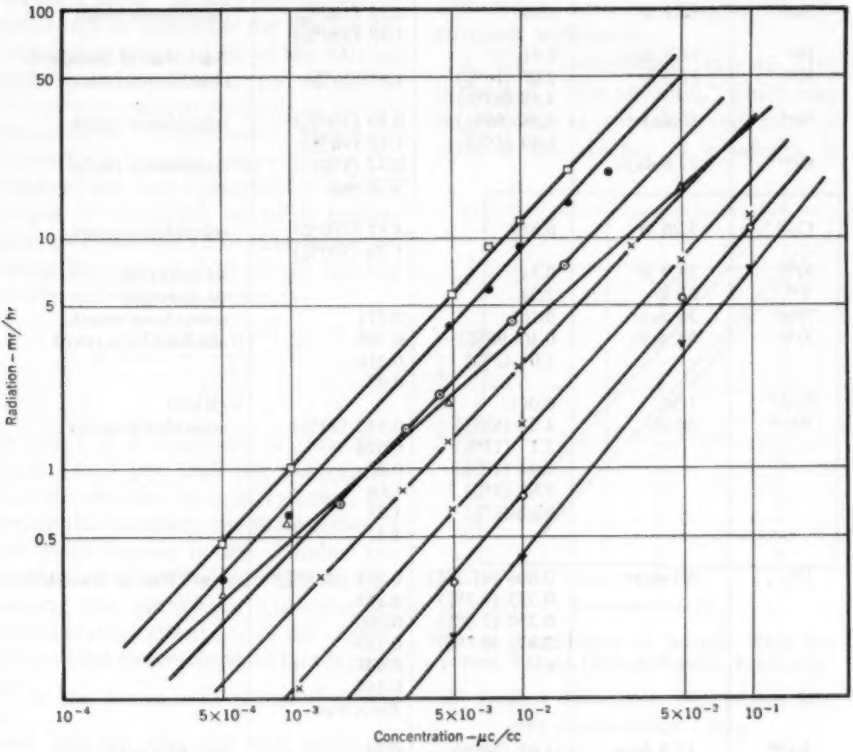

Fig. 3. Concentration Plotted Against Radiation

All values are for submerged readings with Nuclear Corp. meter. Key:

□ Ru^{106}-Rh^{106} △ P^{32} ○ Zr^{95}-Nb^{95}

● Ba^{140}-La^{140} × I^{131} ▼ Tl^{204}

⊙ *Mixed fission products (3 years)* + *Mixed fission products (10 days)*

TABLE 3

Decay Characteristics of Standards

Isotope	Half-Life	Max. Beta Energy *mev*	Gamma Energy *mev*	Activity Determined by
Na^{24}	15.1 *hr*	1.39	2.78 (100%) 1.38 (100%)	coincidence count
P^{32}	14.3 *days*	1.71		Natl. Bur. of Standards
K^{42}	12.5 *hr*	2.07 (16%) 3.58 (84%)	1.51 (16%)	coincidence count
Sc^{46}	85 *days*	0.36 (98%) 1.49 (2%)	0.89 (100%) 1.12 (98%)	coincidence count
Cr^{51}	27.8 *days*		0.32 (9%) V X-ray	coincidence count
Co^{60}	5.26 *yr*	0.319	1.17 (100%) 1.33 (100%)	coincidence count
Sr^{90}	19.9 *yr*	0.54		4π counting
Y^{90}	65 *hr*	2.24		4π counting
Nb^{95}	35 *days*	0.163	0.771	coincidence count
Zr^{95}	65 *days*	0.40 98%) 1.0 (2%)	0.708 0.216 0.92	absolute beta count
Ru^{106}	1 *yr*	0.041		(Rh^{106})
Rh^{106}	30 *sec*	3.53 (68%) 3.1 (11%) 2.44 (12%) 2.0 (3%) high (6%)	0.513 (20%) 0.624 0.87 1.04 1.55 2.41	coincidence count
I^{131}	8.1 *days*	0.606 (87.2%) 0.335 (9.3%) 0.250 (2.8%) 0.812 (0.7%) e^-	0.364 (80.9%) 0.284 0.080 0.720 0.637 0.163 Xe X-ray	Natl. Bur. of Standards
Ba^{140}	12.8 *days*	1.02 (60%) 0.48 (40%)	0.54 0.31 0.16	absolute beta count
La^{140}	40 *hr*	1.32 (70%) 1.67 (20%) 2.26 (10%)	0.33 0.49 0.82 1.60 2.55	absolute beta count
Au^{198}	2.69 *days*	0.97 (99%) 0.29 (1%) e^-	0.41 (99%) 1.09 0.68 Hg X-ray	coincidence count
Tl^{204}	2.7 *yr*	0.783 (98%)	Hg X-ray (2%)	4π counting
Pu^{239}	2.41×10^4 *yr*	5.15 α	0.035 0.050	proportional count

Electroscopes

Electroscopes indicate the amount of ionization produced during radioactive decay by the movement of a hairline across a scale. It was the purpose of this study to determine the relation between this rate of drift of the hairline and the activity of a sample, as well as to compare various methods of sample preparation. Landsverk * and Lauritsen † electroscopes were used. The construction and operation of electroscopes is discussed in most nuclear physics textbooks (*6*). The factor relating the rate of drift of the hairline to the activity of a source is:

$$R = \frac{2.13 \times 10^{-11}\, ki}{C\dfrac{\Delta v}{d}}$$

in which R is expressed in scale divisions (div) per hour per microcurie; k is the fraction of total radiation entering the chamber; i is the number of ion pairs formed in the chamber per particle or quantum entering it (assuming one particle or quantum per disintegrating atom); C is the capacitance of the electroscope, in farads; and $\frac{\Delta v}{d}$ is the decrease in potential difference between wire and wall while the hairline moves through one scale division.

The variables depend on the type and energy of radiation, the physical characteristics of the ion chamber, and the relative position of sample and chamber. The factor R may be either computed from the above expression, if the variables are known, or obtained experimentally, as are the values listed in Table 2.

*Landsverk Electrometer Co., Glendale, Calif.

†F. C. Henson Co., Pasadena, Calif.

Use of Electroscope

The electroscope is used routinely in the following manner:

1. The hairline of the electroscope is deflected to zero by charging the instrument sufficiently.

2. The "background" rate of drift is checked. "Background," which may be defined as the observed rate of drift in the absence of a sample, is caused by a combination of factors, such as leakage of charge, cosmic rays, and radioactive matter in or about the electroscope. The background rate approximates five scale divisions per hour, varying with the location and size of chamber.

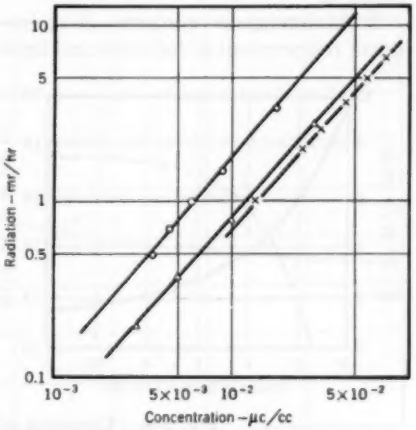

Fig. 4. Comparison of Results With Reported Values (Mixed Fission Products)

All readings were taken with probes held over plastic dishes. Key:

⊙ *3-year-old mixture*
△ *10-day-old mixture*
× Reported (*3*) values

3. A standard source of radioactivity, usually long lived and emitting alpha or beta particles, is used to check

the day-to-day response of the electroscope and to compare the response of various electroscopes. Some of the more frequently used standards are uranium, radium D, Sr^{90}-Y^{90}, and Tl^{204}.

4. The sample is then "counted." For consistency, the time of drift of the hairline is always observed over the same scale interval. To obtain a second reading, the instrument is again charged.

5. Maintenance consists of infrequent replacement of batteries and light bulbs. Detailed instructions are usually provided by the manufacturer.

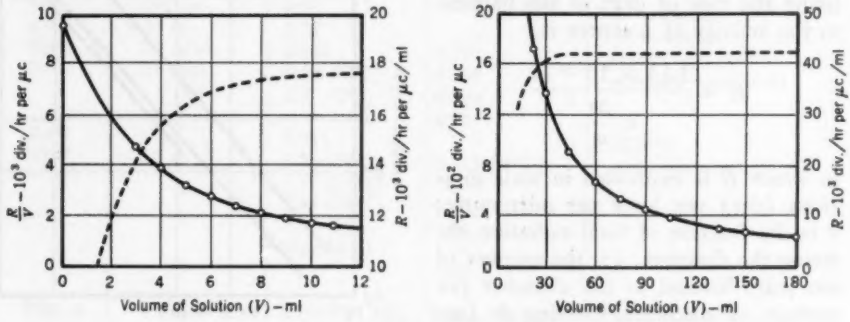

Fig. 5–6. Variation of *R* With Solution Volume

Readings were made with a Landsverk electroscope (Model L–75) on a P^{32} solution in either a 17-ml dish (left graph) or a 200-ml dish (right graph). In both graphs, the $\frac{R}{V}$ *scale applies to the solid line and the* R *scale to the broken line.*

The activity of the sample is found by dividing the rate of drift of the hairline—the ratio of scale divisions to the time of movement—by the factor *R*. If the radioactive constituents of the solution are unknown, the value of *R* is also unknown, and the contents of the solution can be reported only in terms of a standard radioisotope. (The factor *R* for P^{32} being an intermediate one for beta radiation, an unknown beta activity could be reported as "*x* μc in terms of P^{32}.") The amount of ionization caused by alpha, beta, and gamma radiation is roughly in the ratio of $10^4 : 10^2 : 1$. Hence a quick absorption study to determine the type of radiation being detected is advisable.

Sample Preparation

The method of sample preparation selected will depend on the characteristics of the sample. The size of the sample and its distance from the ion chamber are generally fixed, to facilitate comparison of results. The samples may be counted as liquids, or the water may be evaporated from a planchet and the residue counted. Because alpha and weak beta particles are readily absorbed in matter, samples emitting these particles are best placed within the chamber or next to a thin "window" in the chamber wall. Gamma rays readily penetrate matter, so that samples emitting them may be counted when contained in closed vessels. The counting of evaporated samples results in the most precise and

sensitive data, but evaporation cannot be used when volatile radioisotopes are in solution, and may, under certain circumstances, be too time consuming. The amount of radiation detected when liquids are counted increases with depth until an activity plateau is reached, as shown in Fig. 5 and 6. Radiation originating beyond this depth is absorbed in the water before reaching the detector.

tic dishes were located beneath it, after the bottom of the chamber had been removed. The solutions were also evaporated in the aluminum dishes and then counted within the chamber. The values of R that were obtained are listed in Table 2. The factor R for various beta and gamma energies has been calculated and the values are plotted in Fig. 7 and 8. The values are the averages of results obtained

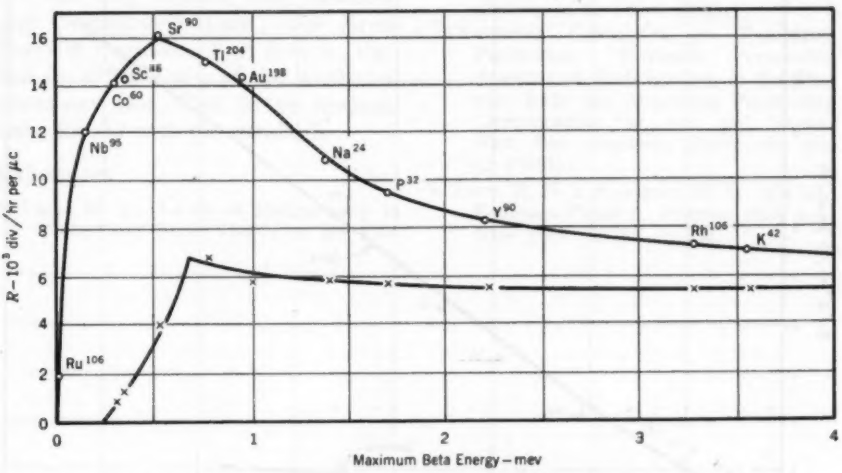

Fig. 7. Observed Variation of R With Maximum Beta Energy

Readings were taken with Landsverk Model L–75 electroscope on thin solid sources in aluminum dishes. The air temperature was approximately 20°C at a pressure of 1 atmosphere. The readings shown on the lower curve were taken on sources covered with an aluminum dish 3.5 mils thick.

Some methods of sample preparation have been studied for use with the Landsverk electroscope, Model L–75. Plastic and aluminum dishes provided with the electroscopes were filled, respectively, with 150 ml and 10 ml of water containing known amounts of the radioisotopes listed in Table 2. The aluminum dishes were placed within the ion chamber, while the plas-

from three electroscopes, whose readings were found to vary linearly with the amount of radiation. Some sources of error in the data are: uncertainty regarding decay scheme and disintegration rate of the standard radioisotopes; uncertainty in measurement of liquid volume, scale reading, and stopwatch reading; variation in specific ionization with temperature, pressure, and hu-

midity; and variation in quantity of radiation detected because of self-absorption in solids contained in the sample (if solution is evaporated).

Discussion

If an instrument is to be useful in assessing radiation hazards, the radiations from a sample containing the maximum permissible concentration of a radioisotope should be readily detected with it. The minimum concentrations (microcuries per milliliter) detectable with the instruments used in this study are of the order of 10^{-6} for alpha, 10^{-4} for beta, and 10^{-2} for gamma radiation. Greater sensitivity can be achieved by concentrating the activity by evaporation. Comparison with published values of maximum permissible concentrations (*5*) indicates that the electroscope may be used to detect these concentrations for most radioisotopes. The suggested maximum permissible concentration of fission products in drinking water for use during a 10-day period after an atomic explosion is 0.09 μc per milliliter (Table 1). As this value is well above the minimum detectable concentration for these electroscopes, they can be used during emergencies. The maximum detectable concentration exceeds the minimum by a factor of 10,000, permitting use of the electroscope over a wide range of concentrations.

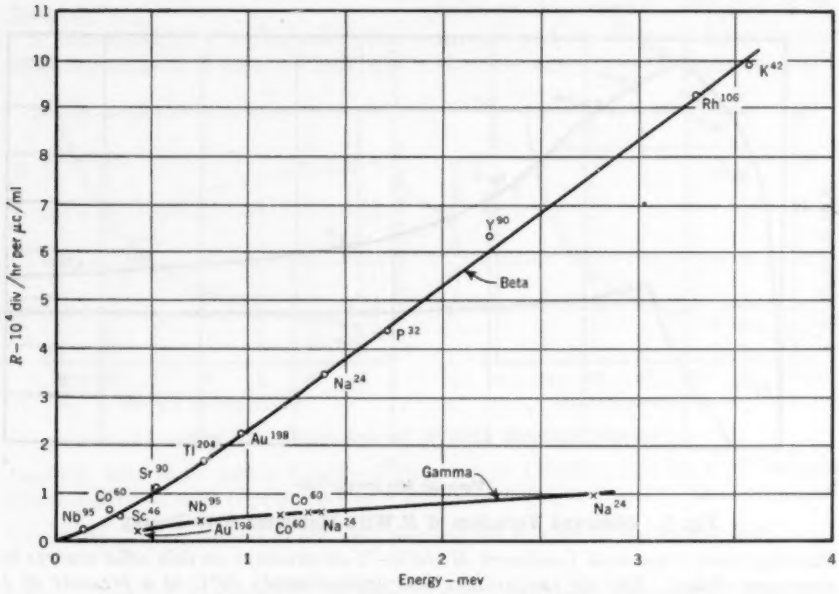

Fig. 8. Observed Variation of *R* With Maximum Beta and With Gamma Energy

Readings were taken with Landsverk Model L–75 electroscope on 150-ml solutions in polystyrene dishes. The air temperature was approximately 20°C at 1 atmosphere.

Acknowledgment

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Reduction of Radioactivity in Water

By Sol Goodgal, Earnest F. Gloyna, and Dayton E. Carritt

A contribution to the Journal by Sol Goodgal, Research Assoc., School of Hygiene & Public Health, Johns Hopkins Univ., Baltimore, Md.; Earnest F. Gloyna, Assoc. Prof., Coll. of Eng., Univ. of Texas, Austin, Tex.; and Dayton E. Carritt, Asst. Prof. of Oceanography, Chesapeake Bay Inst., Johns Hopkins Univ., Annapolis, Md. *These studies were supported by AEC contracts AT(30–1)946 with Johns Hopkins Univ. and W–7405–Eng–26 at Oak Ridge National Lab., Oak Ridge, Tenn.*

THE decontamination of waterborne radioactive wastes is a problem of growing magnitude. The increasing use of radioactive substances by civilian research institutions, hospitals, and industries, as well as the present threat of contamination through military action, suggests that industrial and municipal waste and water treatment plants may soon be required to meet "radioactive specifications" in their products.

The problem of the removal of radioactive substances from water presents nothing fundamentally new to waste and water treatment procedures. It does, however, drastically change the order of magnitude of specifications, some of which already exist. The processes for the removal of calcium from solution, for instance, do not distinguish between radioactive calcium and the inactive calcium familiar as hardness. Whichever type of calcium is involved, it is required that the processes lower the chemical concentration to some specified limit. For radiocalcium in drinking water, the limit is set by the health hazard of the associated radioactivity. Other uses may necessitate lower limits. In the photographic industries, for example, even traces of radioactive substances will fog sensitive films and papers.

Presumably, current waste and water treatment processes may be effective in removing some radioactive elements. Thus, it is reasonable to expect that the processes that now remove calcium, magnesium, iron, and manganese may also be effective in removing radioisotopes of the same elements under comparable conditions. There are, of course, many radioisotopes of elements that have not been met in waste and water treatment practices. Many of the fission products fall into this category. For such elements, the efficiency of current removal practices cannot be estimated. Consequently, a dual problem exists: first, to determine to what extent current treatment practices can furnish products meeting a new set of specifications; and second, to devise new procedures where present ones fail.

This paper outlines the mechanisms by which dissolved substances can be removed from solution; indicates the results of applying commonly used flocculation procedures for the removal of mixed fission products from raw river

water; and describes the application of basic chemical and physicochemical principles to the removal of a single radioactive contaminant, strontium.

Mechanisms for Decontamination

A dissolved substance and its solvent can be separated by changing the phase of either. The solvent may be removed from the contaminant by evaporation and subsequent condensation, or the contaminant may be removed from the solvent by precipitation and subsequent filtration. When large volumes of contaminated liquids must be processed, the high cost of separation by distillation usually forbids its use. Distillation has a distinct advantage over all other procedures, however, in that virtually complete separation of nonvolatile solutes can be achieved.

The experimental work to be described is concerned with the conversion of the dissolved contaminant to a solid. Hahn (*1*) proposed four fundamental processes by which soluble materials may be separated from solution as solids: precipitation, adsorption, isomorphous replacement, and coprecipitation. To these can be added ion exchange, which is formally similar to isomorphous replacement but which, because of recent specialized applications, should be mentioned separately.

These processes can be distinguished and unique properties can be attributed to each of them. It is frequently impossible, however, to predict which

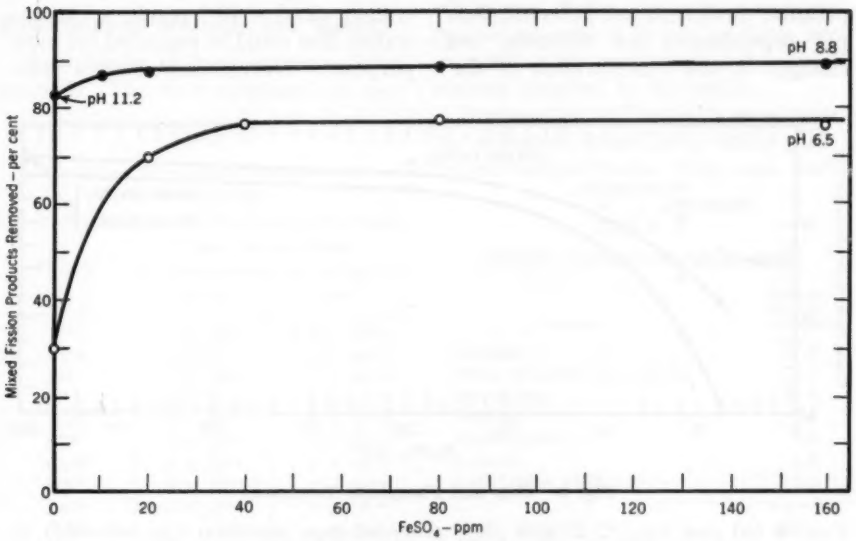

Fig. 1. Effect of Variation in Coagulant Concentration

Key: ○ 15 ppm $Ca(OH)_2$; ● 120 ppm $Ca(OH)_2$. Raw Clinch River water, desilted by settling, was treated with ferrous sulfate and lime. Figures for pH are at time of sampling.

process will be operative during a proposed separation. More often than not, a simple "precipitation" involves two or more of these processes, a fact borne out by the difficulties met in analytical procedures when one attempts to remove a pure compound from solution by precipitation methods.

All of the processes mentioned by Hahn respond differently to changes in environmental conditions: their temperature coefficients are different, their pH dependencies are different, and changes in the concentration of dissolved substances other than those entering the removal reaction produce different effects in each. Measurements of the effects produced by variations of these properties often provide a sufficient basis for deciding which of the processes have been operative during a separation.

Although the removal of radioactive wastes from solution does not involve fundamental changes in water treatment principles, the range of variables is greatly enlarged, particularly with respect to the concentrations in which the contaminant may be found. Frequently the chemical concentration of a radioactive contaminant may be many orders of magnitude below that normally encountered in current water treatment practices, yet above permissible activity limits. For example, the concentration of strontium produced by dispersing 1 g of Sr^{90} in 100 mil gal of water is approximately two parts per trillion (2.65×10^{-6} ppm), a concentration that could be neglected for most purposes. Nevertheless, such a solution would have an activity several hundred times the tolerance for radiostrontium in drinking water. The practical problem, then, would be to reduce by over a hundredfold a substance present initially in a concentration approximately a million times below the permissible limits of most substances normally met in water treatment practice. The maximum permissible drinking water concentration of a number of commonly used radioisotopes is given in Table 1.

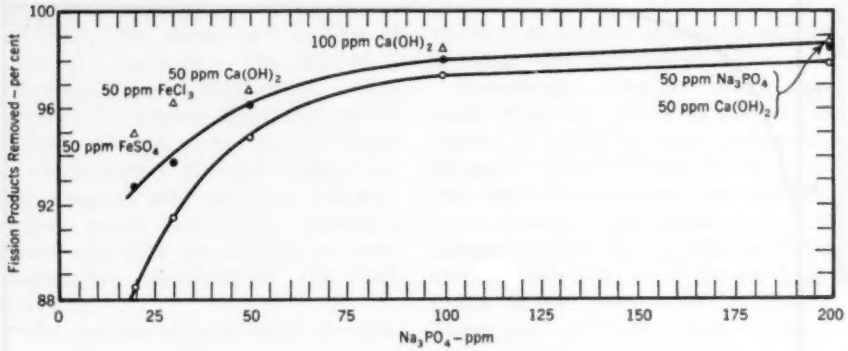

Fig. 2. Clay and Phosphate Treatment

Key: ● 100 ppm clay; ○ 20 ppm clay; △ second-stage treatment (as indicated) of effluent from 100-ppm clay samples. The initial pH was 11.3.

In other situations, the radioactive isotope may be mixed with large quantities of inactive isotopes of the same element. As treatment processes, being chemical in nature, do not distinguish between active and inactive isotopes, it may be necessary to remove relatively large amounts of inactive material in order to insure removal of the active fraction.

Experimental Methods and Results

Two kinds of systems have been studied. The first consisted of raw or treated Clinch River water with added mixed fission products as the contaminant, as well as distilled water solutions of Sr^{90}, both of which were treated only by conventional flocculation procedures (*3*). The second involved distilled water or otherwise chemically defined solutions containing only radiostrontium as the contaminant (*4*).

TABLE 1

Maximum Permissible Concentration of Radioisotopes

Element	Max. Concentration*	
	μc/ml	*ppm*
C^{14}	3×10^{-3}	6.5×10^{-4}
Ca^{45}	5×10^{-4}	3×10^{-8}
P^{32}	2×10^{-4}	7×10^{-10}
S^{35}	5×10^{-3}	1×10^{-7}
Na^{24}	8×10^{-3}	9×10^{-10}
Fe^{59}	1×10^{-4}	2×10^{-9}
Cu^{64}	8×10^{-2}	2×10^{-8}
I^{131}	3×10^{-5}	2×10^{-10}
Zn^{65}	6×10^{-2}	8×10^{-6}
Sr^{89}	7×10^{-5}	3×10^{-9}
Co^{60}	2×10^{-2}	2×10^{-5}
As^{76}	2×10^{-1}	1×10^{-7}

* Maximum permissible concentration in microcuries (*μc*) per milliliter of drinking water, for continuous exposure (*2*); values in parts per million calculated using natural-decay law and published data on half-lives.

The test procedures were similar in all experiments. They consisted primarily either of adding solids directly to the test solutions or of adding reagents that would produce solids by interaction with a solution constituent. After a specified contact time the solids were centrifuged from solution, and usually both the solids and the solution were analyzed for radioactivity. The efficiencies of the treatment processes for the removal of fission products are reported as the percentage of the initial activity removed by the solids.

Analyses for radioactivity were done by accepted procedures, using calibrated Geiger-Muller tubes and scalers. Chemical analyses generally followed *Standard Methods* (*5*).

TABLE 2

Analyses of Mixed Fission Products

Isotopes	Original Mixture *per cent*
Cerium	27.0
Other trivalent rare earths	43.5
Strontium	17.4
Barium	5.1
Ruthenium	2.9
Cesium	1.1
Low fission yield	3.0
Total	100.0

Mixed Fission Products Studies

The percentage composition of the mixed fission products used as added contaminant in Clinch River samples is shown in Table 2. The composition of the coagulants and the decontamination achieved by each are shown in Table 3. In experiments with mixed fission products, the solutions initially contained a carrier-free activity of 120–900 counts per minute (cpm) per milliliter, as registered with an end-on

Geiger-Muller tube having approximately 10 per cent geometry. Unless otherwise specified, samples to which coagulants had been added were allowed to stand for periods comparable to the detention times normally found in practice.

Measurements were made to determine the effect of variations in the concentrations of coagulating agents. The lime–ferrous sulfate system was studied for two concentrations of lime, 15 and 120 ppm $Ca(OH)_2$ with a ferrous sulfate range of 0–160 ppm. The pH was not adjusted but was measured, and, presumably, the values are those that would be obtained under normal treatment with these coagulants. The results are shown in Fig. 1.

Treatment with phosphate at a high pH (Experiment 6, Table 3) provided relatively efficient decontamination, and the natural turbidity of Clinch River water alone (Experiment 5) showed considerable ability to "carry" the fission products when it was centrifuged from the mixture. The combined effects of suspended and preformed solids (clay) and phosphate treatment were further examined: contaminated tap water was treated with 20 and 100 ppm of clay, sodium phosphate being added in amounts varying from zero to 200 ppm. The solutions obtained by centrifuging out the solids from the samples treated with 100 ppm clay and phosphate were further treated with other coagulants. The pH was ini-

TABLE 3

Removal of Mixed Fission Products *

Experiment No.	Coagulants		Final pH	Radioactivity Removed† *per cent*
	Type	Amount *ppm*		
1	lime	120	11.8	83.8
2	lime	120		
	soda ash	20		
	ferric chloride	40	11.8	89.4
3	lime	120		
	ferrous sulfate	40		
	soda ash	20	11.5	90.6
4	lime	100		
	sodium silicate	10	10.8	91.6
5‡	control*		8.4	58.0
6‡	trisodium phosphate	100	12.2	92.2
7‡	calcium carbonate	20	8.4	68.3
8‡	soda ash	20	8.4	70.2

* Raw Clinch River water turbidity 70 ppm; pH 8.4; and alkalinity 92 ppm ($CaCO_3$).
† Based on the supernatant count of the centrifuged sample as compared with the original count in the liquid.
‡ Special treatment procedures used.

tially adjusted to 11.3 in all of these experiments. The results are shown in Fig. 2.

Radiostrontium Studies

It is difficult to learn from the results of the mixed fission product experiments which of the several radioisotopes in the mixture were removed by treatment and which of the processes suggested by Hahn were involved in the separation. Therefore, it is hard to make a rational revision of the processes to achieve more efficient decontamination. It appeared reasonable that at least a part of the information needed for such a revision could be obtained by studying solutions of an individual fission product element under conditions that would allow the observed behavior to be described in terms of known chemical and physicochemical properties of the element and its environment. Strontium, which accounts for more than 17 per cent of the mixed fission products, was therefore studied under a wide variety of treatment conditions, and an attempt has been made to establish the processes responsible for its separation.

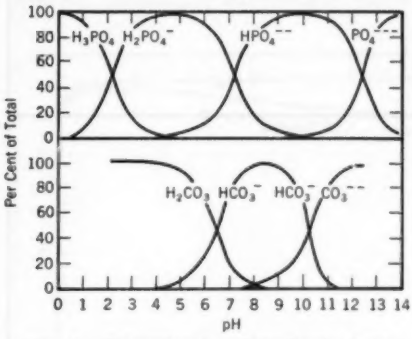

Fig. 3. Phosphoric and Carbonic Acid Ionization as Function of pH

The upper graph is based on data from Kolthoff and Sandell (7); the lower, on data from Latimer (6). Ionization constants are shown in Table 4.

Solutions of carrier-free radiostrontium (Sr^{89} and Sr^{90}) were prepared from a stock, designated ORNL Unit No. 38-FA, obtained from Oak Ridge National Lab. These solutions had a total-strontium concentration similar to that of the mixed fission product solutions. Solutions of varying total-strontium concentration were prepared by the addition of inactive strontium nitrate to the carrier-free solutions and by dilution of ORNL Unit No. 38, a solution of Sr^{89} containing inactive strontium.

TABLE 4

Solubility Products and Ionization Constants

Compound	Solubility Product*
$Sr(OH)_2$	3.2×10^{-4}
$SrCO_3$	9.42×10^{-10}
$Sr(HCO_3)_2$	1.83×10^{-6}
$SrSO_4$	2.8×10^{-7}
	Ionization Constant†
H_3PO_4	7×10^{-3}
$H_2PO_4^-$	7×10^{-8}
HPO_4^{--}	4×10^{-13}
H_2CO_3	4.3×10^{-7}
HCO_3^-	4.7×10^{-11}

* Data from Latimer (6).
† Phosphoric acid data from Kolthoff and Sandell (7); carbonic acid data from Latimer (6); see Fig. 3.

It has been noted that the most efficient decontamination of mixed fission product solutions occurred at a high pH. For strontium, this behavior can, under some conditions, be related to the solubility of compounds that might be formed during treatment. The solubility product expressions for several such compounds are given in Table 4.

Strontium phosphate, $Sr_3(PO_4)_2$, and $SrHPO_4$ are reported to be slightly soluble, but no solubility product information could be found. Seidell (*8*) indicates that, under some conditions, a slightly soluble dimer, $(SrHPO_4)_2$, is formed. The treatment of the solubility of strontium phosphates on the basis of solubility products is at present confused; despite the fact that insoluble phosphate compounds are reported, it is possible that, under some conditions, phosphate may have a sequestering action on insoluble strontium compounds similar to its action on calcium compounds.

The anions of each of these slightly soluble strontium compounds are anions of weak acids. Thus, the concentrations (actually, the activities) that appear in the solubility product expressions are controlled by pH. The dependence of the solubility of strontium hydroxide on pH is obvious. That the solubilities of the carbonates and phosphates are also dependent on pH is indicated in Fig. 3, in which the ionization of the carbonic and phosphoric acids is shown as a function of pH. Consequently, the amount of strontium remaining in solution after precipitation is a function of pH, as well as of the amount of precipitant added during treatment. The further practical significance of the magnitude of the solubility product values and the ionization of the weak acids will be discussed later.

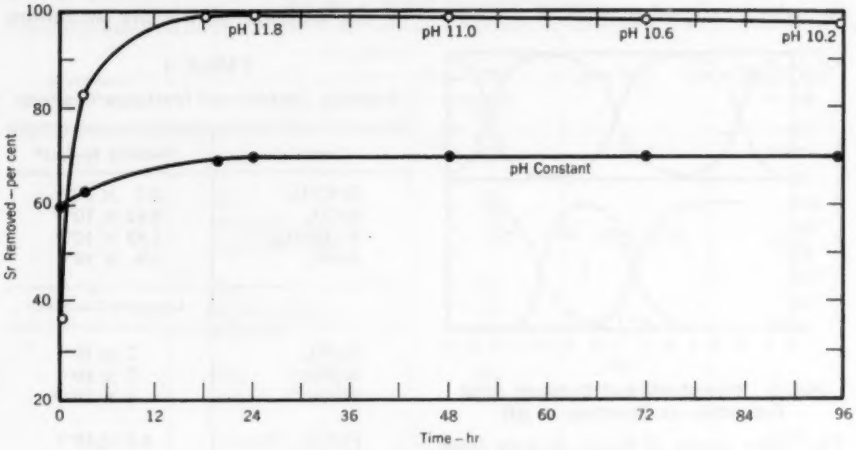

Fig. 4. Effect of Aeration

Key: ○ in contact with air; ● air excluded. The strontium concentration, as $Sr(NO_3)_2$, was 41 ppm (0.00047 M). The initial pH was 12.2.

Alkaline solutions, from which the most efficient fission product removal was obtained, will absorb carbon dioxide from the air. This condition favors the formation of carbonate in solution, and, under the proper conditions, the precipitation of carbonates will occur. Thus, treatment of alkaline solutions in contact with air may actually result in carbonate treatment

even though carbonate was not added. This effect was measured for the strontium system by comparing the behavior of two sets of solutions, one agitated in contact with air and the other sealed except during sampling. All samples contained 41 ppm of strontium as $Sr(NO_3)_2$ plus tracer quantities of radiostrontium, and were adjusted initially to pH 12.2 with sodium hydroxide. Two systems were examined under aerated and air-excluded conditions; one was treated with 100 ppm of potassium dihydrogen phosphate, while the other contained no phosphate. Samples were withdrawn periodically for 96 hr; the pH was measured; the solids were removed by centrifugation; and the solids and the supernatant solution were analyzed for radiostrontium. The results are shown in Fig. 4 and 5.

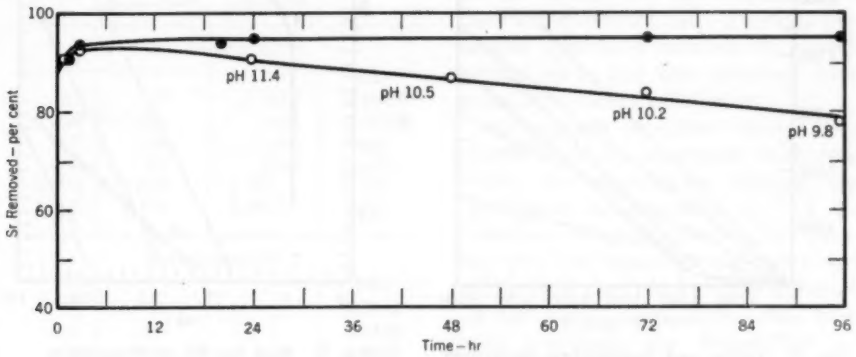

Fig. 5. Effect of Aeration (Phosphate-treated Samples)

Key: ○ in contact with air; ● air excluded. The phosphate concentration, as KH_2PO_4, was 100 ppm (0.000735 M). The initial pH was 12.2.

The behavior of the solutions that contained no phosphate can be explained in terms of carbonate precipitation and absorption of atmospheric carbon dioxide. In the sample equilibrated out of contact with the air, strontium carbonate precipitated until the carbonate present initially in the solutions had been reduced to saturation concentration at the existing strontium ion concentration. There being no external source of carbonate, the system reached equilibrium and no further change occurred after approximately 24 hr. In the solution in contact with the air, carbon dioxide was continually absorbed, furnishing a source of carbonate sufficient to precipitate nearly all of the strontium as strontium carbonate. As the solutions were poorly buffered, further absorption of carbon dioxide produced a lowering of the pH and resulted in the solution of some of the strontium carbonate.

The behavior of the phosphate-treated samples is not as clearcut as that of the untreated samples. At pH 12.2, the concentrations of phosphate and monohydrogen phosphate are nearly equal (Fig. 3). The solid phase formed in such a solution could

then be $Sr_3(PO_4)_2$, $SrHPO_4$, or the dimer, $(SrHPO_4)_2$, suggested by Seidell, or a mixture of all of them. Because the solubility products are unknown, there is no way of deciding which compounds actually precipitated. The sample equilibrated in contact with the air clearly shows an increased solubility with decreasing pH. Even though carbon dioxide was absorbed, however, the precipitation of strontium carbonate appears to have been suppressed, as the amount of strontium remaining in solution was greater in phosphate-treated samples than in comparable phosphate-free solutions.

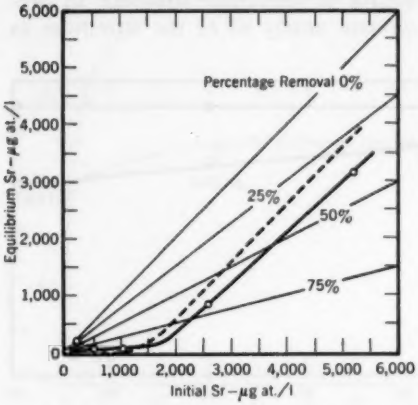

Fig. 6. Initial and Equilibrium Strontium Concentrations

The solid line (with circles) indicates the experimental results, while the broken line shows the expectation from theory, based on the solubility product of $SrCO_3$.

These experiments indicate that, at a comparable pH, strontium phosphates are more soluble than the carbonate; in fact, phosphate has a solubilizing effect during the precipitation of strontium carbonate. This effect is similar to that described by Reitemeier and Ayers (*9*) for the calcium carbonate–metaphosphate system, in which the presence of as little as 3 ppm of sodium metaphosphate prevented the precipitation of calcium carbonate.

Adsorption Studies

It was noted in the mixed fission product experiments that suspended solids carried an appreciable fraction of the activity when centrifuged from solution. A possible mechanism for such behavior is the adsorption of the dissolved contaminant on the surface of the solids or the exchange of a solid constituent for one in solution.

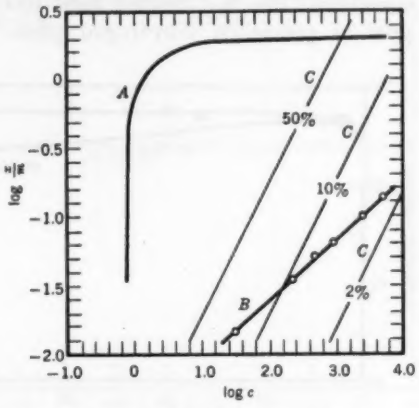

Fig. 7. Test for Fit to Freundlich Isotherm

Key: A—*theory (from $SrCO_3$ solubility product)*; B—*Experiment 121*; C—*lines of constant percentage removal of strontium. Curves* A *and* C *assume strontium is removed on 728 ppm solids.*

The behavior of the strontium–suspended solids system was studied to learn to what extent and under what conditions adsorption might account for the removal of strontium from solution. From the results of experi-

ments previously described, it is clear that, in alkaline solutions, the precipitation of strontium carbonate might mask an adsorption reaction, especially in solutions containing carrier strontium. An attempt was made to determine the contribution of each of the two reactions to the observed strontium removal, by comparing the behavior of two systems: one at a pH high enough to form only carbonate and so favor the precipitation reaction, and the other at a pH low enough so that essentially no carbonate ion existed, thus suppressing the precipitation reaction. All solutions were kept in sealed containers and were opened only for sampling. Samples for analysis were withdrawn from the solutions periodically for 24 hr. All of the systems reached equilibrium in less than 30 min, and frequently no appreciable change was found after 5 min. The initial conditions, results of analyses, and pertinent calculable quantities for the two systems are given in Table 5.

TABLE 5

Precipitation and Adsorption Tests

Sr—μg at./l*			$\frac{x}{m}$
Initial	Measured Equilibrium	Calculated† Equilibrium	μg at./mg‡
Experiment 120§			
52	27	0.75	0.0343
260	208	0.82	0.0720
520	69	1.06	0.613
1,040	68	2.60	1.322
2,600	830	1,200	2.41
5,200	3,170	3,800	2.76
Experiment 121‖			
52	31.5		0.0144
260	235		0.0350
520	484		0.0500
1,040	994		0.0629
2,600	2,530		0.0964
5,200	5,100		0.135

* Microgram atoms per liter.
† From $SrCO_3$ solubility product, 9.42×10^{-10}.
‡ Microgram atoms Sr removed per milligram added solids.
§ Initial conditions: pH 11.3; added solids 728 ppm; CO_3^{--} 1,667 μg at. per liter.
‖ Initial conditions: pH 7.4; added solids 728 ppm; CO_3^{--} negligible.

That the behavior of the system at a high pH consists essentially of the precipitation of strontium carbonate is shown in Fig. 6, where the initial strontium ion concentration has been plotted against the equilibrium strontium ion concentration. There is reasonable agreement between the experimental curve and that obtained from solubility product calculation.

Adsorption reactions have been characterized by adsorption isotherms, which are expressions relating the equilibrium concentration (c) of the substance being adsorbed to the quantity (x) of adsorbed substance per unit weight (m) of adsorbing material. Of the many relationships that have been proposed, the Freundlich, or classical, isotherm appears to be the most useful. It has the form:

$$\frac{x}{m} = kc^{1/p}$$

in which k and p are constants. This equation can be put in the form:

$$\log \frac{x}{m} = \log k + \frac{1}{p} \log c$$

Systems which obey this equation should yield data showing a linear relationship between $\log \frac{x}{m}$ and $\log c$. The data from Experiment 121 have been so treated, and the results are shown in Fig. 7. Such a linear rela-

tionship would also exist if the decontamination mechanism were to remove a constant fraction of the initial strontium—that is, when $p = 1$ in the Freundlich isotherm. Figure 7 shows this situation for 2 per cent, 10 per cent, and 50 per cent removal from a solution of the same composition as those tested in Experiment 121. Also plotted is a curve based on solubility product data.

For the system examined in Experiment 121, the Freundlich isotherm is:

$$\frac{x}{m} = 0.0032\, c^{0.44}$$

in which c is in microgram atoms strontium per liter, x is in microgram atoms strontium, and m is in milligrams.

Evaluation

The experiments in which mixed fission product decontamination was attempted by conventional treatment procedures indicate the relative efficiencies of the procedures and show that none of them will provide adequate decontamination when used as a single-stage treatment operation. Although the analyses of the effluents from these experiments gave no indication which of the activities had been removed, thus making impossible an assessment of the efficiency of decontamination in terms of the maximum permissible concentrations of each of the components, several general conclusions can be drawn. The most important are that the greatest decontamination efficiency is associated with a high pH and that naturally occurring suspended solids "carry" an appreciable fraction of the activity when removed from solution.

The pH effect suggested that precipitation of compounds formed from anions of weak acids, such as carbonates and phosphates, might have been the mechanism by which the activity was removed. The action of suspended solids suggested an adsorption or exchange mechanism. The behavior of strontium, one of the components of mixed fission products, was studied under conditions that would accentuate each of the processes.

The precipitation of strontium carbonate was found to follow the behavior predictable from its solubility product, with only minor variations. It is possible, then, to set rather well defined limits to the extent to which radiostrontium-bearing solutions can be decontaminated by precipitation of strontium carbonate. The maximum permissible concentration of Sr^{90} in drinking water is of the order of 2×10^{-6} μc per milliliter, or $1.7 \times 10^{-18} M$. In order to reduce strontium to this concentration, the carbonate ion concentration must be raised to approximately 6,000 M, obviously an experimentally unattainable condition. Thus, adequate decontamination of carrier-free Sr^{90} solutions cannot be achieved by precipitation of strontium carbonate. The situation can be improved, however, by the addition of inactive strontium to the Sr^{90}-contaminated solution prior to carbonate treatment. Under this condition, the concentration of strontium remaining after treatment will not be reduced, but the Sr^{90} remaining will be decreased by a factor proportional to the ratio of inactive to active strontium. The concentration of inactive strontium that must be added to a solution contaminated with 1 μc of Sr^{90} per milliliter is calculated below.

Let (Sr_0^*) be the initial concentration of Sr^{90}, 1 μc per milliliter or 7×10^{-8} M. Let (Sr_0) be the initial concentration of inactive strontium, that is, the concentration that must be established prior to carbonate treatment. Let (Sr^*) and (Sr) be the concentration of the two species after treatment. As precipitation is nonselective:

$$\frac{(Sr_0)}{(Sr_0^*)} = \frac{(Sr)}{(Sr^*)} \quad \ldots\ldots (1)$$

But (Sr^*) is defined as the maximum permissible concentration in the effluent:

$$(Sr^*) = 1.7 \times 10^{-13}\ M \ldots . (2)$$

From the solubility product of strontium carbonate, the conditions after treatment must be:

$$[(Sr) + (Sr^*)][CO_3] = 9.4 \times 10^{-10} \ldots (3)$$

In a system with a pH greater than 11, so treated that the CO_3 concentration will equal $9.4 \times 10^{-3} M$ (1,000 ppm Na_2CO_3) after treatment:

$$[(Sr) + (1.7 \times 10^{-13})][9.4 \times 10^{-3}] = 9.4 \times 10^{-10}$$

or:

$$(Sr) = 1.0 \times 10^{-7}\ M \ldots . (4)$$

Substituting the appropriate numerical values in Eq 1:

$$(Sr_0) = 4.1 \times 10^{2}\ M$$

This means in order to reduce Sr^{90} contamination from 1 μc per milliliter to the permissible level for drinking water by strontium carbonate precipitation, the initial concentration of inactive strontium must be raised to more than 400M, again an experimentally unattainable condition. Apparently, then, single-stage precipitation of strontium carbonate cannot be relied upon to reduce Sr^{90} activity levels of this order to the maximum permitted in drinking water.

The decontamination that can be achieved by taking advantage of adsorption on suspended solids can be calculated from the adsorption isotherm previously determined. The expression is:

$$\frac{x}{m} = 0.0032\ c^{0.44}$$

If it is desired to reduce the Sr^{90} activity to the maximum permissible limit of 2×10^{-6} μc per milliliter (1.4×10^{-7} μg at. per liter) from a carrier-free activity of 1 μc per milliliter (7×10^{-2} μg at. per liter), c in the isotherm becomes 1.4×10^{-7}, x is ($7 \times 10^{-2} - 1.4 \times 10^{-7}$), and m, the concentration of solids that must be added, can be calculated. A solution of the isotherm for these conditions indicates that treatment with 23 g of added solids per liter will provide the necessary decontamination. Thus, whereas the development of a treatment process which relies on precipitation as the removal mechanism appears to be impossible, an adsorption process can achieve the required decontamination, even though, on the present scale of treatment, it seems impractical.

In addition to implied uses in treatment systems, the adsorption reaction described is an important consideration in assessing the factors that will control the dispersal of radioactive wastes in natural aquatic systems. In many natural systems, equilibrium between soluble and adsorbed wastes undoubtedly will not occur. It is reason-

able to assume, however, that an appreciable fraction of a radiostrontium waste will become associated with naturally suspended solids and that, in part, the dispersal and ultimate distribution of the waste will follow that of the solids.

Acknowledgment

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Thallium as a Reference Standard for Beta Radioactivity

By A. G. Wheler Jr., S. A. Reynolds, and W. A. Brooksbank Jr.

A contribution to the Journal by A. G. Wheler Jr., Radioactive Liquid Waste Research & Development Section, Health Physics Div. (now with Allied Chemical & Dye Corp., Hopewell, Va.); S. A. Reynolds, Analytical Chemistry Div.; and W. A. Brooksbank Jr., Analytical Chemistry Div.; all of Oak Ridge National Lab., Oak Ridge, Tenn.

IT is becoming increasingly apparent that a standardized method of determining radioactivity in streams and water supplies is needed. A variety of methods is in use today by a number of states making measurements of radioactivity present in their streams. It is not very difficult to determine the alpha activity in a water supply (*1*), but beta radioactivity offers a more complex problem. The types and decay energies of radioisotopes present are generally unknown. Assays from various locations are not comparable and are often meaningless.

Brooksbank and Reynolds suggested Tl^{204} as a standard of comparison for use at the various Atomic Energy Commission plants (*2, 3*). This isotope has proved to be a reliable tool which gives reproducible results. Reynolds also outlined the use of Tl^{204} at the Boston, Mass., meeting of the Beta and Gamma Ray Measurements and Standards Subcommittee of the National Research Council, Oct. 23–24, 1952. The subcommittee recommended further investigation. The use of this standard will give an efficiency correction for the entire technique employed, without a series of individual corrections for self-absorption, window thickness, and other factors. Wheler, while at the Massachusetts Institute of Technology, used some accurately standardized Tl^{204}, obtained from Reynolds, in making assays of tolerance levels of beta activity in water supplies and found that it gave statistically valid results (*4*).

Suggested Procedure

The following procedure for use of the thallium standard is suggested. Suitable equal aliquots of the standard are added to solutions containing various amounts of solids. These are dried on counting dishes, weighed to determine amounts of solids, and then counted in the usual way. An efficiency curve, such as in Fig. 1, can then be plotted, efficiency being defined as counts per minute of standard divided by disintegrations per minute of standard.

When an unknown sample is run, the amount of solids is determined by weighing the counting dish, drying a sample on the dish, and reweighing the dish. The efficiency curve may then be used to convert from counts per minute to microcuries per milliliter in

terms of Tl^{204}. The latter unit is suggested for use in reporting activity values based on thallium, although it may be different from "absolute microcuries per milliliter." If it is desired, the standard Tl^{204} samples may be counted daily to establish efficiency, instead of using a calibration curve. In this way, the slight counter variations will be compensated.

It is suggested that the following detailed procedure be considered:

1. Select a cup or counting dish that will hold a reasonable volume for final evaporation of sample. The cup should be of sufficient thickness to develop maximum backscatter. For example, a steel cup of 0.0117-in. wall thickness was used at the Massachusetts Institute of Technology.

2. Establish a system of source support so that the standardized cup will always have exactly the same relation to the horizontal and vertical axes of the Geiger-Muller tube or counting chamber of the proportional counter. This procedure is necessary to keep the geometry constant.

3. Also for this reason, evaporate the standardized samples of Tl^{204} in the same way as the water samples are to be prepared. Use the standardized samples to determine the efficiencies of the counters under the conditions outlined in Step 2.

4. Determine the total solids in the water sample in question. When the activity of samples is in the range of 10^{-7} μc per milliliter or less and the solids are in the range of 200 ppm or less, evaporate 750 ml of sample to concentrate enough activity for detection.

In the light of the usefulness of Tl^{204}, it is recommended as a reference standard for determining beta radioactivity in streams and water supplies. A standardized method of estimating radioactivity would permit comparisons of results from different locations and would give an accurate picture of how the beta radioactivity in streams and water supplies is changing with time, thus enabling the detection of potential health hazards. Such a method would be analogous to the coliform organism test, which, although it does not show how many pathogenic bacteria are contained in a water sample, does indicate the probability that pathogens may be present. In a similar manner, Tl^{204} as a reference standard will indicate the order of magnitude of radioactivity in a stream.

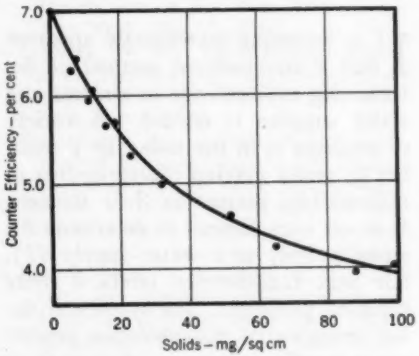

Fig. 1. Typical Tl^{204} Efficiency Curve

Efficiency is defined as counts per minute of standard divided by disintegrations per minute of standard.

The proposed nuclide, Tl^{204}, has a beta energy of 0.78 mev (*5*) and 2 per cent K-capture, resulting in Hg X-rays (*6*). Its half-life is approximately 2.7 years. The beta energy is close to the average of the beta energies occurring in a reasonably old fission product mixture, a type of ma-

terial commonly encountered in low-level work. Also, this energy is generally typical of other mixtures, and the efficiency curves of most counters show an essentially flat region for beta energies above that of thallium.

When there is a demand for the thallium standard, the radioactivity section of the National Bureau of Standards will standardize a stock solution at a concentration of 10^{-3} microcuries (μc) per milliliter. This material would be made available to those who wish to use it on the same basis as the bureau's standards for I^{131}, P^{32}, and certain other radioisotopes. For the present the Tl^{204} radioisotope furnished by the AEC Isotopes Div. could serve as a standard, because the concentration is known within 10 per cent.

Conclusion

A standardized method of beta counting, such as the Tl^{204} method, will prove useful in background surveys on streams, in checking higher levels of activity in water, and in radioactive waste disposal. The procedure has the merit of referring radioassays to a standard that will have meaning in the future when better methods are available. By making all background surveys referrable to one another, such standardized surveys would indicate how the background in streams is changing with time and whether a potential health hazard is developing.

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Continuous Production of Activated Silica With Carbon Dioxide Gas

By Robert V. Andrews

A contribution to the Journal by Robert V. Andrews, Assoc. Research Engr., Texas Eng. Experiment Sta., Texas A. & M. College, College Station, Tex.

THE use of activated silica as a coagulant aid in water treatment is increasing in importance. Its growing use, together with the mounting costs of labor and materials, makes it highly desirable to develop cheaper and simpler methods of producing it. Accordingly, a pilot plant was designed to manufacture activated silica continuously, employing the simplest and most economical equipment possible.

In addition to the already recognized advantages that activated silica has in comparison with other coagulation aids —greater effectiveness in cold weather and over a broader pH range, as well as the production of a tougher, denser floc, which settles more rapidly and thus increases filter capacities—the use of this material has certain advantages where radioactive-particle removal is of major concern. One black photographic wrapping paper manufacturer has found that activated silica employed as a coagulant aid along with standard alum coagulation is highly effective in removing traces of radioactivity from water. The radioactive contamination apparently originated occasionally in the air over the water supply and was not removed by the usual water treatment methods. Some batches of paper contained sufficient radioactivity to expose photographic film wrapped in it. When activated silica and alum were used to treat the water, no radioactive difficulties with the paper were encountered.

The original activated silica process, developed by Baylis (*1*) in 1936, utilizes a 1.5 per cent SiO_2 solution of sodium silicate partially neutralized with dilute sulfuric acid. The general chemical reaction involved is:

$$Na_2O \cdot SiO_2 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O + {}^{-}SiO_2{}^{-}$$

In place of sulfuric acid, it is possible to use other acids, ammonium salts, complex phosphates, borax, sodium bicarbonate, chlorine, or carbon dioxide. The activated silica produced is a negatively charged colloidal particle that is aged to permit the growth of silica or silicate micelles. When the particle size has increased to the desired point, the solution is diluted to an equivalent 0.6 per cent SiO_2 or less, to prevent further growth. If the solution is not stabilized by dilution at the desired point, the solution will eventually gel. The factors influencing the activity and stability of activated silica sols have been discussed by Henry (*2*) and Merrill (*3*). Some neutralizing agents, such as sulfuric acid, produce a sol that

gels relatively slowly, if proper equivalent concentrations of SiO_2 and degrees of neutralization are used, but requires aging for 1–2 hr to produce the desired activity. Carbon dioxide, on the other hand, produces a sol that is active almost immediately, needing little or no aging; over quite a wide range of neutralization, gelling is postponed long enough to permit effective use if continuous production of the sol is practiced.

Batch Method

At present most plants using activated silica prepare the sol by a batch method. In the Chicago South Dist. Filtration Plant, where sulfuric acid is used as the neutralizing agent, sodium silicate and sulfuric acid are kept in storage tanks, diluted separately, and then brought together in a batch reaction tank to form a sol approximately 85 per cent neutralized, with an equivalent 1.5 per cent SiO_2 concentration. The sol so formed is aged for approximately 2 hr, diluted to a 0.6 per cent equivalent SiO_2 concentration, and stored for future use. Duplicate processing equipment must be maintained to prepare one batch while another is being utilized.

At the Miami, Fla., Southwest Water Treatment Plant carbon dioxide is used as the neutralizing agent in another batch process. An equivalent 1.5 per cent SiO_2 sodium silicate solution is stored and activated in a large concrete tank, in the bottom of which a perforated-pipe grid system is installed to permit the blowing of diesel engine exhaust gas through the liquid. The exhaust gas contains an average of 3 per cent carbon dioxide and partially neutralizes the sodium silicate to produce the active sol. Approximately 50 per cent neutralization is produced in 30 min of gas flow, and the sol is used with no aging other than that due to retention time in the tank. No dilution for stability is needed under normal operating conditions, as the tank of sol is completely used before gelling can occur. Under these conditions, the gel time would greatly exceed a week. Duplicate facilities are provided.

Offsetting the advantages of carbon dioxide gas as a neutralizing agent in the preparation of activated silica is the fact that the methods now used employ a batch system of sol manufacture. The batch system requires at least a duplication of equipment, as well as more physical space and more operating labor. A continuous process of manufacture would be highly desirable, particularly one using carbon dioxide obtained from engine exhaust or boiler flue gas. Such a system apparently has not been adopted previously because of a lack of experimental data permitting its application to commercial, plant scale water treatment. The pilot plant described later in this paper produced activated silica continuously, using pure carbon dioxide as the neutralizing agent for the dilute sodium silicate solution. The substitution of a flue gas for the pure carbon dioxide gas is now being studied.

Pilot Plant Design

The pilot plant arrangement is shown in Fig. 1. Essentially, the plant consisted of two orifice mixers with vertically positioned orifice plates, one to dilute the sodium silicate to the desired equivalent SiO_2 concentration, and the other to react the carbon diox-

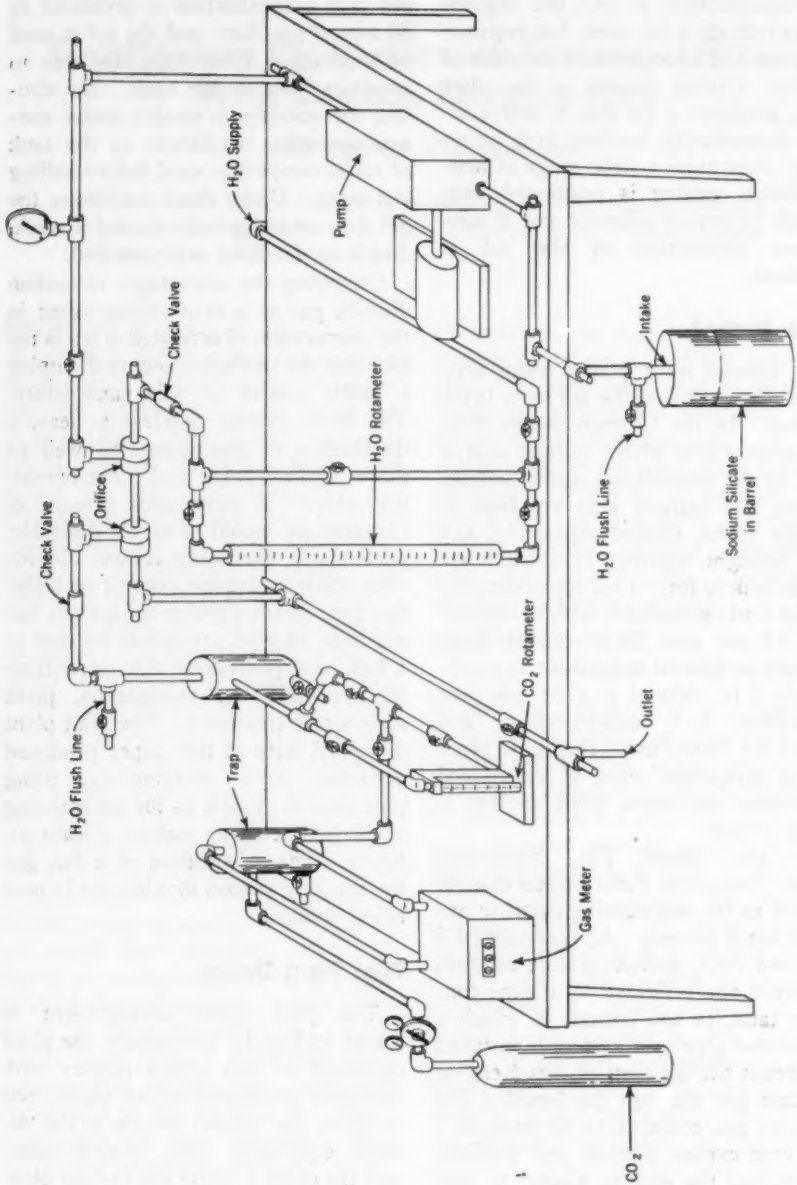

Fig. 1. Pilot Plant Layout

ide with the diluted sodium silicate.* Undiluted sodium silicate was fed to the pilot plant by means of a proportioning pump, and treated city water was supplied through a rotameter to a point just upstream from the orifice. The two were mixed in passing through the orifice, to produce a dilute sodium silicate solution of uniform concentration.

Carbon dioxide gas from a standard steel cylinder was passed under pressure through a rotameter and then added to the line carrying the diluted sodium silicate at a point just upstream from a second vertical orifice. The latter served to mix the carbon dioxide and dilute sodium silicate uniformly, causing the carbon dioxide to neutralize a part of the alkalinity of the sodium silicate. Gas feed rates were roughly controlled by a standard, adjustable pressure-reducing valve on the carbon dioxide cylinder and were accurately controlled by a globe valve in the line, just preceding the gas rotameter.

The apparatus was constructed entirely of $\frac{1}{8}$-in. pipe in order that turbulent flow conditions could be maintained in the lines within the range of capacities of the proportioning pump. In place of standard pipe ells and tees, plugged pipe tees and crosses were used as shown in Fig. 1, to permit easier cleaning out of the lines should gelation occur within them. The pipe system also was constructed so that the entire line, including the sodium silicate pump and the gas line up to the carbon dioxide rotameter, could be flushed with fresh water when the manufacture of activated silica was stopped. The flushing provision is extremely important, because plugging of the lines occurs very rapidly on shutdown if any sodium silicate remains in the pipes. The use of plugged pipe tees and crosses proved unnecessary when flushing facilities were provided. During 3 months of intermittent operation no plugging occurred, and examination of the pipes at the end of this period showed no deposit on the inside. The use of such fittings would add little to the expense of a plant, however, and would materially reduce the labor cost of cleaning, as well as the "down time," should gelling ever occur in the lines.

The two orifices for mixing and reacting were of standard design, machined from steel stock in a local shop. A single flange tap was used upstream from the orifice for introducing water or carbon dioxide, and the ratio of inside pipe diameter to orifice diameter was 3.023. One of the duplicate orifices is shown in detail in Fig. 2.

Experimental Runs

Turbulence in the pipeline was assured by employing Reynolds numbers (R) of the liquid flow in the range of 3,500–6,500, with R being calculated for conditions existing in the line rather than in the orifice.† A value of $R = 2{,}100$ is nominally considered the breakover point from viscous to turbulent flow. Thus, the turbulence through the orifice when R ranged from 10,000 to 20,000 would be considerably greater than in the pipeline itself, but flow in the pipeline proper would be sufficiently turbulent to keep concentration gradients over the pipe cross section to a minimum.

* *N* brand sodium silicate, a product of Philadelphia Quartz Co., was used for all tests.

† The Reynolds number equals the inside pipe diameter (ft) times the linear velocity of the liquid (fps) times the liquid density (lb per cu ft) divided by the liquid viscosity (lb per ft sec).

Concentrations of sodium silicate, measured as percentage SiO_2, were investigated in the 1–3 per cent range, with carbon dioxide addition rates ranging from 0.3 to 0.8 cfm (60°F at 1 atmosphere), actually supplied at 35 psi gage.

neutralization was based on the chemical reactions:

$$Na_2O \cdot SiO_2 + CO_2 \rightarrow Na_2CO_3 + SiO_2$$

$$Na_2CO_3 + H_2O + CO_2 \rightarrow 2NaHCO_3$$

The first reaction represents 50 per

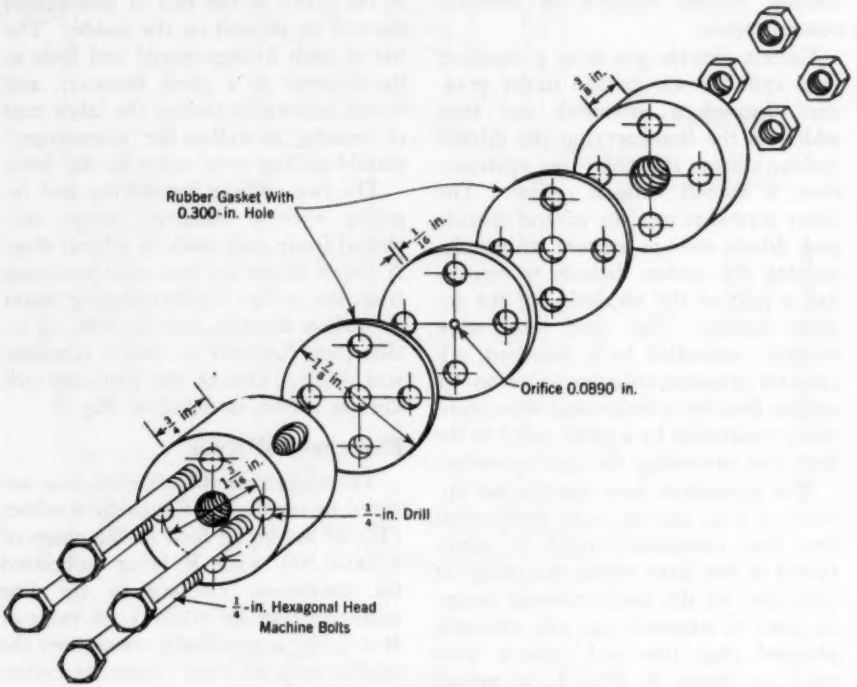

Fig. 2. Orifice for Pilot Plant System

Two such orifices are employed in the system. Their location is shown in Fig. 1. All tapped holes are for 1/8-in. pipe.

To obtain a maximum amount of information with a minimum number of experimental runs, a "Latin square" arrangement of runs was first undertaken. This arrangement is shown in Table 1, together with the percentage neutralization obtained. Percentage

cent neutralization; that is, the point at which the alkalinity of the sodium silicate has been converted completely to sodium carbonate but no sodium bicarbonate has been produced. The second reaction represents 100 per cent neutralization, with all the alkalinity of

the sodium silicate converted to sodium bicarbonate. The percentage neutralization was calculated from the results of the standard differential titration of samples of the sol produced with 0.1*N* sulfuric acid solution (*4*).

The data obtained from the nine runs of the Latin square were valuable in establishing the quantitative effects of the three variables: R, CO_2 addition rate, and percent SiO_2 content. Neutralizations from less than 50 per cent to 100 per cent were obtained, the percentage increasing with a rise in the carbon dioxide addition rate and decreasing as both R and equivalent percentage SiO_2 concentrations increased.

TABLE 1

Latin Square Data

R	CO_2 Rate*—*cfm*		
	1% SiO_2	2% SiO_2	3% SiO_2
3,500	0.397 (100%)	0.540 (82.01%)	0.718 (68.5%)
5,000	0.540 (100%)	0.718 (80.18%)	0.397 (64.24%)
6,500	0.718 (99.56%)	0.397 (69.52%)	0.540 (61.0%)

* Figures in parentheses represent percentage neutralization.

Additional experimental runs were then made with five carbon dioxide addition rates at each of the three pipeline R values (3,500, 5,000, and 6,500) and for each of three equivalent SiO_2 concentrations. The data obtained from these runs are shown in Table 2 and are plotted in Figure 3. Cross plots of the data were used to obtain the 3 per cent SiO_2 lines of Fig. 3a and 3c.

Jar Tests

Jar tests using a synthetic water were employed to check the activity of the sols produced. The synthetic water was made up by suspending fuller's earth in treated city water, and the same synthetic water was used to test all sol samples. This water gave a reading of 85 on a logarithmic-scale photoelectric turbidimeter and had a pH of 7.01. One sample of the synthetic water was treated with 50 ppm of alum only, while others were treated with 50 ppm of alum and 20 ppm of the activated silica to be tested. The activated silica was always freshly prepared and was used with less than 5-min possible aging. With alum treatment alone, the pH of the synthetic water was reduced to an average value of 6.55, and the turbidity was reduced

TABLE 2

Percentage Neutralization of Sodium Silicate

R	CO_2 *cfm*	Neutralization—*per cent*		
		1% SiO_2	2% SiO_2	2.8% SiO_2
3,500	0.243	100	75.42	63.10
	0.307	100	78.66	66.20
	0.397	100	80.64	67.48
	0.540	100	82.01	71.20
	0.718	100	82.99	71.98
5,000	0.243	100	70.59	56.47*
	0.307	100	73.38	60.44*
	0.397	100	77.08	64.24*
	0.540	100	78.11	66.64*
	0.718	100	80.18	65.39*
6,500	0.243	85.91	63.99	55.49†
	0.307	86.95	67.82	58.23†
	0.397	93.02	69.52	58.01†
	0.540	96.64	72.05	64.04†
	0.718	99.56	72.05	65.73†

* 3 per cent SiO_2.
† 2.6 per cent SiO_2.

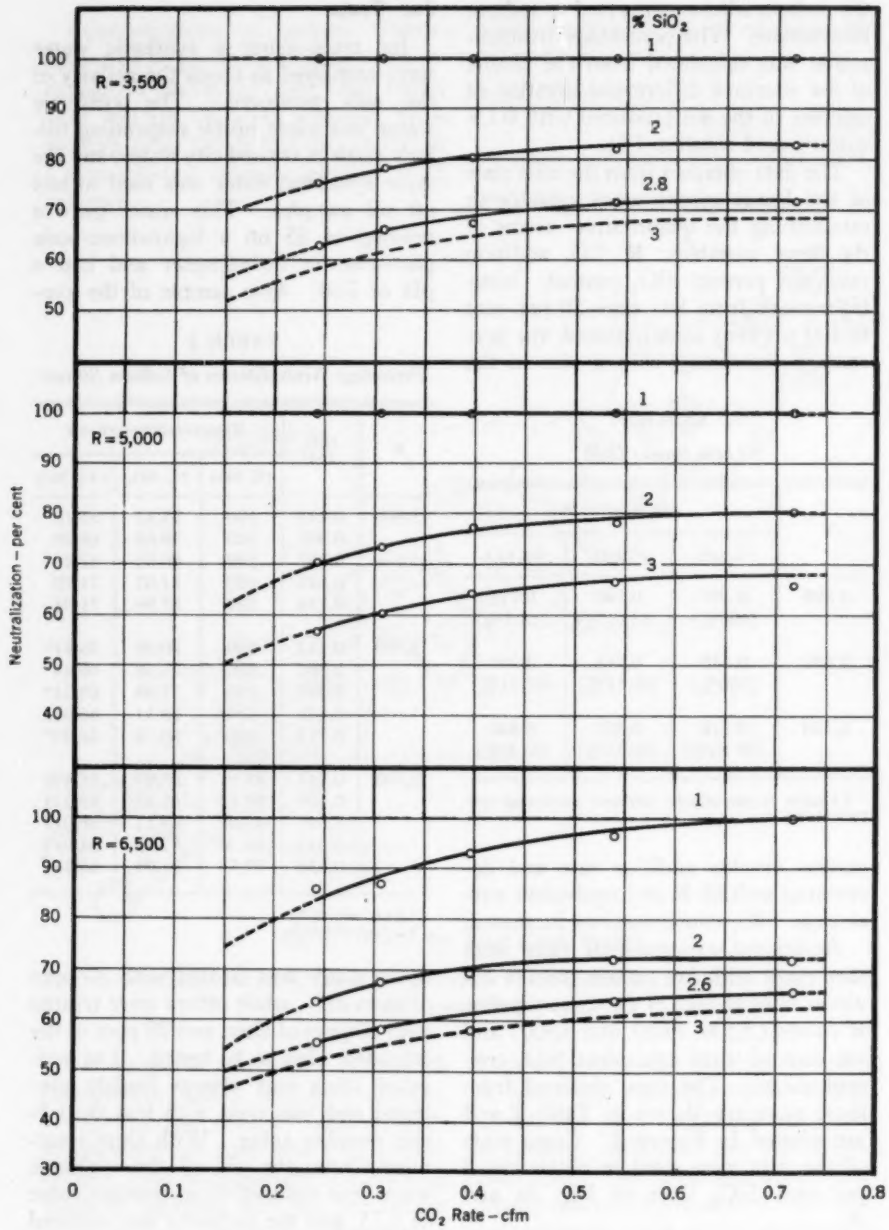

Fig. 3. Neutralization and Carbon Dioxide Rate

to an average reading of 2.61. The samples treated with alum and activated silica had an average pH value of 6.63 and an average turbidity reading of 2.47. Although a slight trend toward increasing pH and decreasing turbidity readings seemed to exist with increasing percentage neutralization of the sol samples, the change was so small as to be of doubtful significance. Apparently very little real difference in activity of the sols actually existed.

The effectiveness of the sol as an aid in removing turbidity from water was not much greater than that of alum alone, but the size of the floc particle formed and its settling rate were enormously increased. The addition of activated silica and alum produced a floc particle approximately ten times the size of that of alum alone, and its settling rate was such that, at the slow-speed agitation for aging in the jar test, the floc particles could not be kept in suspension. Instead, they tended to settle in the jar and form a cone-shaped pile beneath the stirrer paddle. (A picture of a typical floc formation is shown in Figure 4.) The increased size of the floc particle, however, did not lessen its effectiveness in removing turbidity.

As the **R** value—and, therefore, the linear velocity of the liquid in the pipe—decreased, the percentage neutralization of the sol increased, for any given rate of carbon dioxide addition. This was to be expected, because the driving force for the neutralization reaction was greater at the lower linear velocities. The employment of excessively low linear velocities, however, might lead to gelling difficulties, owing to locally occurring high concentrations of sodium silicate in the solution and abnormally high percentage neutralization. This effect would probably be particularly noticeable in the region where the flow pattern changes from turbulent to streamline. This fact, together with the slight difference in effectiveness of the sol for higher per-

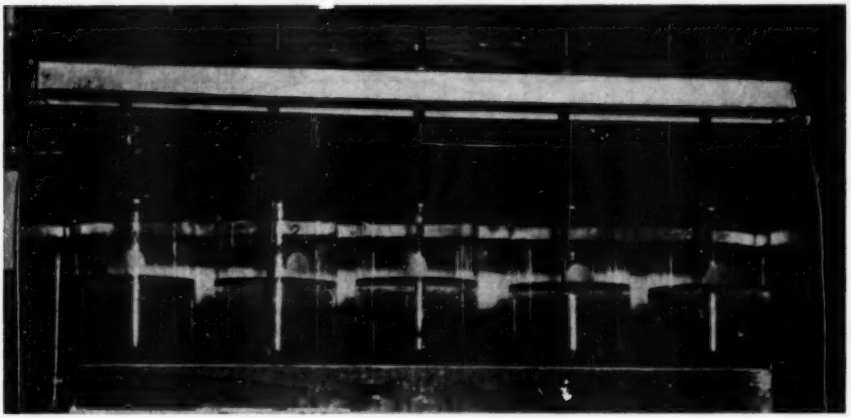

Fig. 4. Typical Floc Formation

The jar at left contains alum only; the others, alum and activated silica.

centage neutralizations, dictates the use of higher values of **R** and lower values of percentage neutralization.

Other Experiments

In addition to using vertically oriented orifice plates, several runs of the pilot plant were made with horizontally oriented plates. Previous experience in using orifice mixers on liquids had indicated that the horizontal orientation of the orifice plate gave best results. In the range of these experiments, however, identical results were produced with both orientations. No advantage of one over the other could be determined.

To supplement the standard jar tests performed, a flume system, with baffles and settling basin, was set up as shown in Fig. 5. Alum was added at the head of the flume, and activated silica from the pilot plant was fed into the baffle system in the first chamber after the alum addition. With the addition of the activated silica, the floc

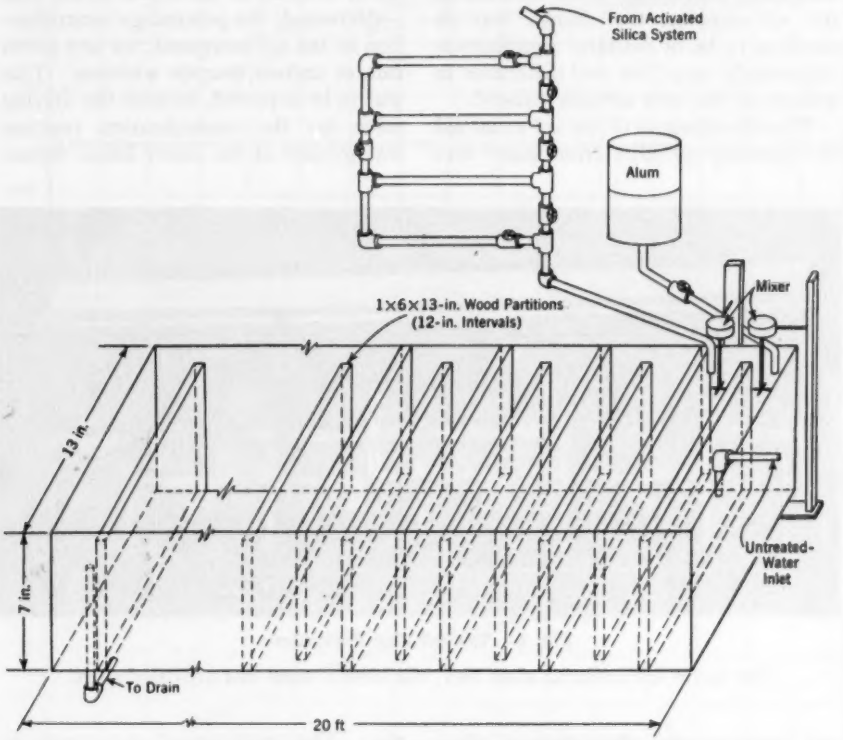

Fig. 5. Flume System With Baffled Settling Basin

This equipment was operated continuously for 8-hr periods to simulate actual water plant treatment.

formed was much larger and settled much more rapidly than did the floc formed by alum alone. This equipment for testing the sol was operated continuously for 8-hr periods to simulate water plant treatment as nearly as possible. In all tests made, the activated silica sol proved beneficial and highly desirable as a coagulant aid.

Because the data of Henry (*5*) have shown that, within a limited range, the activity of a sol is improved by age, a piping manifold was included with the baffled flume system to provide up to 10 min of aging of the activated silica before use. Some slight trend toward increase in activity took place with aging, but the results in this time range were not sufficient to be conclusive or to warrant the cost of the piping manifold.

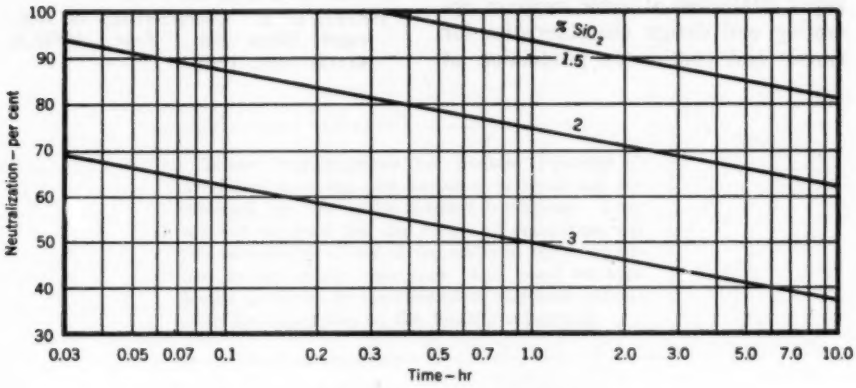

Fig. 6. Gel Time of Activated Silica Sols

This graph is based on data from Henry (5).

Conclusions

The results of these experiments indicate that a satisfactory activated silica can be produced continuously over a very wide range of conditions. For commercial operation, however, it is recommended that 0.5 cfm of CO_2 gas, supplied at 35 psi gage, be used with a 3 per cent equivalent SiO_2 sodium silicate solution and a pipe flow Reynolds number of 5,000. A 3.023 ratio of inside pipe diameter to orifice diameter can then be expected to give a sol 65 per cent neutralized. Under these conditions, a gel time of 4 min may be anticipated, as shown in Fig. 6. This gel time is long enough to avoid any difficulties with gelling in the pipeline and, together with the neutralization, is enough to insure adequate activity when the gel is used immediately after preparation.

The cost of a plant like that described is relatively small, compared with the expense of batch systems using the same process. The major cost item is the proportioning pump. A pump adequate to prepare activated silica for treating 10 mgd with a dosage of 20 ppm can be obtained for approxi-

mately $900. Piping, valves, and fittings can be obtained for a normal installation at a cost of another $100. The instrumentation necessary for the simplest operation would also amount to approximately $100. Assuming $400 for contingencies, local manufacture of orifices, and miscellaneous items, the total capital investment comes to $1,500.

Previous investigators have established the desirability of using activated silica as a coagulant additive. It is believed that the work described in this paper establishes a usable range of operating and design characteristics for simple and continuous production of activated silica with pure carbon dioxide gas on a commercial scale.

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American Water Works Association

Tentative

Standard Specifications

for

SODIUM PYROSULFITE

These "Specifications for Sodium Pyrosulfite" are based upon the best known experience and are intended for use under normal conditions. They are not designed for use under all conditions and the advisability of use of the material herein specified in any water treatment plant must be subjected to review by the chemist or engineer responsible for operations in the locality concerned.

Approved as "Tentative" Dec. 18, 1953

- **Price of reprint—20¢ per copy**
- **Approximate date available—Mar. 15, 1954**

AMERICAN WATER WORKS ASSOCIATION
Incorporated
521 Fifth Avenue, New York 17, N.Y.

Tentative Standard Specifications for

Sodium Pyrosulfite

Part A—Material Specifications

Sec. 1A—Scope

These specifications cover sodium pyrosulfite ($Na_2S_2O_5$) for use in the treatment of municipal and industrial water supplies. The specifications are intended for use in connection with Part B (Sampling, Inspection, Packing, and Marking) and Part C (Testing Methods) of this document.

Sec. 2A—Definition

Sodium pyrosulfite ($Na_2S_2O_5$), otherwise known as anhydrous sodium bisulfite or sodium metabisulfite, is a manufactured product. It is a white crystalline powder readily soluble in water, in which it produces an acid reaction. It is employed in water treatment for the removal of chlorine (analagous to sulfur dioxide treatment). It is a very efficient dechlorinating agent; 1.34 parts by weight of $Na_2S_2O_5$ react with 1 part of chlorine:

$$Na_2S_2O_5 + 2\,Cl_2 + 3\,H_2O \rightarrow 2\,NaHSO_4 + 4\,HCl$$

Sec. 3A—Sampling

Sampling shall be conducted in accordance with Part B (Sampling, Inspection, Packing, and Marking) of this document.

Sec. 4A—Methods of Testing

The laboratory examination shall be carried on in accordance with Part C (Testing Methods) of this document.

Sec. 5A—Impurities

The sodium pyrosulfite supplied under these specifications shall contain no soluble mineral or organic substances in quantities capable of producing deleterious or injurious effects upon the health of those consuming the water which has been treated properly with sodium pyrosulfite.

Sec. 6A—Rejection

6A.1. Notice of dissatisfaction with a shipment based on these specifications must be in the hands of the consignor within 10 days after receipt of the shipment at the point of destination. If the consignor desires a retest, he shall notify the consignee within 5 days of receipt of notice of the complaint. Upon receipt of the request for a retest, the consignee shall forward to the consignor one of the sealed samples taken in accordance with Sec. 2B. In the event that the results obtained by the consignor, on retesting, do not agree with the results obtained by the consignee, the other sealed sample shall be forwarded, unopened, for analysis, to a laboratory agreed upon by both parties. The results of the referee test shall be accepted as final, and the cost of the referee analysis shall be paid for by the party whose results show the greatest discrepancy from the referee analysis.

6A.2. On the basis of the retest or the referee test, the consignor may remove the material from the premises of the consignee, or a price adjustment may be agreed upon by the consignor and consignee.

Sec. 7A—Size

Sodium pyrosulfite shall be free from lumps and foreign matter and shall be a free-flowing powder satisfactory for use in a dry-feed machine.

Sec. 8A—Available Sulfur Dioxide

Sodium pyrosulfite shall contain not less than 65.7 per cent available sulfur dioxide (SO_2), which is equivalent to 97.5 per cent sodium pyrosulfite ($Na_2S_2O_5$).

Part B—Sampling, Inspection, Packing, and Marking

Sec. 1B—Scope

These procedures for the sampling, inspection, packing, weighing, and marking of sodium pyrosulfite are intended for use with Part A (Material Specifications) and Part C (Testing Methods) of this document.

Sec. 2B—Sampling

2B.1. Samples shall be taken at the point of destination.

2B.2. Not less than 5 per cent of the packages or containers shall be sampled. No sample shall be taken from a broken package or container.

2B.3. Sodium pyrosulfite may be sampled by the use of a sampling tube which is at least ¾ in. in diameter.

2B.4. The gross sample, weighing at least 10 lb, shall be thoroughly mixed and quartered to provide three 1-lb samples. They shall be sealed in airtight, moistureproof, dark-colored glass containers. Each sample container shall be labeled to identify it, and the label shall be signed by the sampler. When sampling, the material shall be handled rapidly and carefully to avoid loss of sulfur dioxide.

Sec. 3B—Packing and Shipping

3B.1. Sodium pyrosulfite may be shipped in 100-lb multiwall paper bags, 400-lb fiber drums, or 430-lb tight, hardwood, paper-lined barrels.

3B.2. The net weight of the packages shall not deviate from the recorded weight by more than ± 1 per cent. If exception is taken to the weight of the material received, it shall be based on the certified unit weight of not less than 10 per cent of the packages shipped and selected at random from the entire shipment.

Sec. 4B—Marking

Each shipment of material shall carry with it some means of identification. Each package shall have marked legibly thereon the net weight of the contents, the name of the manufacturer, and the brand name, if any. The package may bear also the statement: "Guaranteed by (name of manufacturer) to meet the specifications of the American Water Works Association for sodium pyrosulfite."

Part C—Testing Methods

Sec. 1C—Scope

These methods for the examination of sodium pyrosulfite are intended for use in connection with Part A (Material Specifications) and Part B (Sampling, Inspection, Packing, and Marking) of this document.

Sec. 2C—Sampling

2C.1. Sampling shall be conducted in accordance with Part B (Sampling, Inspection, Packing, and Marking) of this document.

2C.2. The sample of sodium pyrosulfite shall be quartered carefully and rapidly to approximately 100 g. After thorough mixing, the sample shall be stored in a dark-colored glass container. The sample shall be kept in a dark, cool, dry place and the container kept closed except when portions are being weighed from it. This will avoid loss of sulfur dioxide.

2C.3. The laboratory examination of the sample shall be completed within 5 working days after receipt of the shipment.

2C.4. Samples shall be stored at least 30 days from the date of receipt before disposing of them.

Sec. 3C—Available Sulfur Dioxide

3C.1—*Reagents:*

(a) 0.1*N* iodine solution

(b) 0.1*N* sodium thiosulfate solution

(c) Freshly prepared starch solution.

3C.2—*Procedure:*

3C.2.1. Weigh accurately 0.43–0.47 g of the sample of sodium pyrosulfite and transfer quickly to a 500-ml Erlenmeyer flask containing 100 ml of 0.1*N* iodine solution.

3C.2.2. Mix until all the sample is dissolved, and titrate the excess iodine with 0.1*N* sodium thiosulfate solution until the iodine color has decreased to a faint yellow. Add 1 ml of starch solution and continue the titration until the blue color just disappears.

NOTE: If the iodine is decolorized when the sample is dissolved, discard the analysis and start over, using a smaller weight of sample. An excess of iodine must be present to avoid loss of sulfur dioxide.

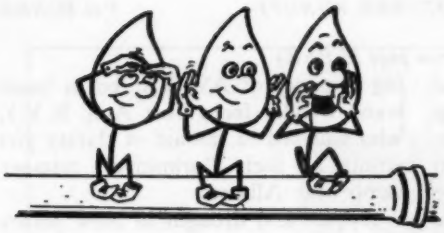
3C.3—*Calculations:*

$$[(100 \times \text{normality of iodine soln.}) - (\text{ml thiosulfate soln.} \times \text{its normality})] \times 10 = \text{ml } 0.1N \text{ iodine soln. used}$$

$$\frac{(100 - \text{ml } 0.1N \text{ sodium thiosulfate}) \times 0.3203}{\text{weight of sample}} = \text{per cent } SO_2$$

or:

$$\frac{(100 - \text{ml } 0.1N \text{ sodium thiosulfate}) \times 0.4753}{\text{weight of sample}} = \text{per cent } Na_2S_2O_5$$



Percolation and Runoff

Gold bricks seem to be in season these days as much because of the march of science as despite it, for science has been accomplishing such unbelievable things that the less-than-expert in any field is likely to feel closed minded and a little inadequate unless he makes himself receptive to every seemingly serious suggestion of something new and wonderful, particularly if the suggestion is reassuringly couched in mellifluous reconditeness. No longer able to ignore financial fruits that have justified continued nationwide advertising of a number of these profound-sounding devices in the most expensive popular media, we are now preparing to board the gravy train ourself with the "P&R Quaternary Aqualitizer." A-powered and H-controlled, this four-in-one watermate combines a conditioner designed to provide direct dishalogenization, a corrosion controller guaranteed to inactivate *Tubercula pitinthepipus,* a scale remover operating on basic piscalaminar principles, and a softener so effective that water hammer is completely eliminated. Because the Aqualitizer is so revolutionary in principle that its secret must be kept, no patent application has been filed. Instead, the Aqualitators have been made air-sensitive and then are vacuum-sealed in the Aquitainer, there to function almost indefinitely. As any exposure to the atmosphere will instantaneously disintegrate the functioning elements, there is, of course, no danger of competitive infringement.

Despite that fact, to any member of AWWA who requires help of the type that the Aqualitator is guaranteed to give, we offer our special 100 per cent member discount and instructions on installing the device by thinking it into the system. The thinking actually seems to help.

Rhabdomanticana of every description have tempted us almost constantly since we forswore our browsing into dowsing last January. Thus, on this anniversary of our eschewal, we cannot resist a recess, if only to list the temptations resisted, month by month:

February, for instance, found us approached by the Treasure Trove Club (J. Frank Dobie—Mr. Treasure Hunter 1953) for a copy of our January dowsing notes to use in the "Treasure Review" column of its *Rainbow Hobby News.*

March brought warning from the antiskeptic Mr. Roberts not only that Henry Gross was to ride again, but that "skeptics who have refused to accept the facts revealed by dowsing are endangering the vital water resources of the country."

April introduced an inquiry by Arthur Gilbert, editor of the British *Waterworks Officers' Journal,* into the possibilities of a scientific explanation

(Continued on page 34 P&R)

(*Continued from page 33 P&R*)

for divining, from which he later in the year concluded that "water divining seems still to be in the realms of controversy," but though there "seems to be no scientific reason for it," we shouldn't write it off entirely unless we are prepared to admit that we know all the mysteries of science. Meanwhile, out at UCLA's Institute of Geophysics, there appeared a much less (to us) mysterious dowsing implement based upon electromagnetic ore-prospecting techniques. Like Henry Gross' rod, this device was said not only to locate water, but to judge its quality; it differed, however, in its use of electrical conductivity, rather than twig conduct, as a means of measurement.

May featured a *Fortune* advertisement in which Clearing Machine Corp. called dowsing "an idea with little more than time to honor it," and likened the practice to the unreasoned preference for cast, over pressed, metals. Then the spring issue of the Illinois Health Dept.'s *Over the Spillway* two-taled the welding rod dowser for pipe locating, while *Wastes Engineering* carried news of a rather Soviet-sounding claim by Water-Rods Co., Gloversville, N.Y., that they had developed the device.

June turned our radio to Station WJR Detroit, where Edgar Guest's son, Bud, included in his "Sunny Side of the News" a full account of wire water witcher Walter Klepfer, who almost single-handedly almost solved the drought problems of Texas merely by dipping his copper wire dowsing piece in water and then coaxing it to point out more than 60 wells.

July slightly gilded the Walter lily with *United Press* coverage which sought to satisfy science with the fact that the Klepfer copper was a conductor. Brought to the fore, too, was Frank Jordan (not the late gavel-wielding exprexy of AWWA, but a hazel wand wielder from Fort Ann, N.Y.), who whisked to the aid of thirsty girl scouts at their "primitive" summer camp near Albany.

August and drought in New Jersey aimed fame at a peach-twig peripatetician, named Charlie Decker, who was given full credit for keeping the corn fat and the grass green in the vicinity of Butler, N.J., by exercising his allergy-like reaction to water.

September returned Henry Gross to the front page of the Boston *Sunday Herald* in the full glory of his "extraordinary achievements" in long-distance map dowsing, following the precept of Kenneth Roberts' *Seventh Sense.*

October was given to more scientific investigation: by S. Jepson in the *Waterworks Officers' Journal* on divining in India; by Rollin Beaver in the *Water Well Journal* on farm water witching; and by Howard A. Meyerhoff in *Popular Science* on the geologist's viewpoint. Only in India did dowsing come out on top, and that, of course, is on the other side of the world.

November brought us still more scientific stuff, in a manuscript by the English naturalist, Eric Hardy, and in an old letter by Thomas G. Sydnor, founder of the Sydnor Pump & Well Co., both of which strongly supported dowsing. The fact that Hardy based his acceptance on the British Army's recognition of the art and the fact that Sydnor's handholding dowsing lessons had led him to his wife raised some slight question concerning scientific validity.

Now in December, though, we're not the least bit inclined to draw our own conclusions, lest Santa Claus hold them against us.

(*Continued on page 36 P&R*)

don't be half safe

A satisfactory palatable water is never achieved by inadequate, halfway dosages of Aqua Nuchar Activated Carbon. To be certain that all the algae and trade waste odors are adsorbed, the correct amount of Aqua Nuchar *must* be applied.

Water plant operators and superintendents often try to cut corners by stretching out the minimum dosage to cover periods of maximum requirements. They should know that consistent feeding of Aqua Nuchar Activated Carbon will keep the plant seeded—thus easing the problem of controlling sudden surges of intense odors in the raw water. Extremely heavy dosages under heavy pollution loads are minimized.

It requires a very sensitive sense of smell to differentiate between a threshold odor of 50 and 25. The chances are that your average consumer could not tell the difference. Therefore, being *half safe* is not enough! Threshold odors should be in the range of 5 to be certain of delivering a palatable water.

Complaints from consumers can so easily be avoided if you will take advantage of Industrial's Technical Service Department and call on the Aqua Nuchar Threshold Odor Experts to make a survey of the plant which they will do without obligation. Following this, they will recommend how to use Aqua Nuchar with your other chemicals and where to apply it for optimum water palatability.

Send your problems to our nearest office and our Technical Service Department will be glad to study them.

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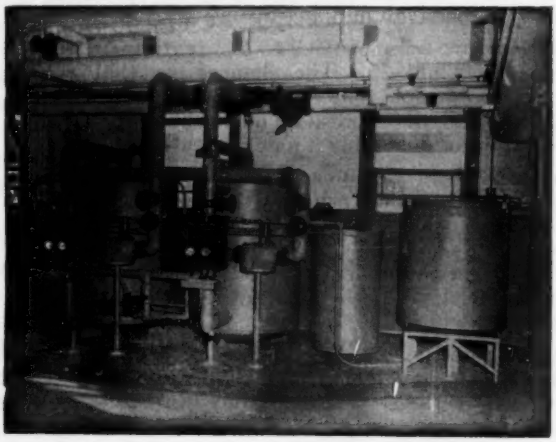
(*Continued from page 34 P&R*)

Topics discussed last month at the Mid-century Conference on Resources for the Future (see November P&R, p. 36) included the prospect of increasing water supplies—although at higher cost—in the Southwest; the sharing of pollution control responsibility between town and factory; and various problems of ground water conservation. Even before the by no means harmonious proceedings began, a major argument arose over the composition of the 1,500 delegates, and ended with the withdrawal of the public power representatives, who charged that corporate interests demoniated a "stacked" convention.

Louis F. Frazza, of Johns-Manville's Transite Pipe Section, has been nominated to become vice-president of the Northeastern Area, National Society of Professional Engineers.

Water in politics, which we were pushing just a couple months ago as the way of getting politics out of water, has just manifested itself in an unexpected way in the election of water worker Joseph P. Lawlor as Mayor of Ames, Iowa. Of course, Lawlor, as president of the General Filter Co., is from the peddling end of the water business, but his basic engineering background and his 32 years in the water works field make him a pinup politician as far as we're concerned. Working with Mayor Lawlor in the administration of city affairs—which include operation of a municipal water treatment plant and system—will be not only a six-member council, but a city manager in a city that pioneered that plan of government. All of which bodes well for Ames' aims in water supply.

(*Continued on page 38 P&R*)



Water Softening & Iron Removal* *Deluxe*

JUST WHAT YOU'VE BEEN WAITING FOR—

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All in one single, compact, highly efficient water conditioning plant

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CLAYTON 5, NEW JERSEY

STEEL PIPE helps cut cost of Philadelphia's long-range program of waterworks improvement

The tracks you see in the photo below are part of the Pennsylvania Railroad's main line. That's one reason why the pipes passing under the tracks are built of strong, *electric welded steel.*

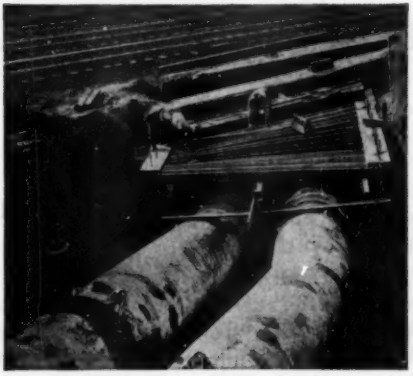
Engineers know from experience that Alco Electric Welded Steel Pipe has the strength and resilience to absorb vibration, impact and overloading that destroy pipe of other types. They know, too, that Electric Welded Steel Pipe offers still other advantages that help cut piping costs. For example: *Efficiency*—smooth, tar-enameled inside surface gives excellent rate of flow. *Economy*—not only is first cost low but sections are long and light, for fast, easy installation. And *durability*—estimated life is 75 to 100 years.

Alco makes Electric Welded Steel Pipe to meet AWWA and other specifications. Forty-foot lengths fabricated without girth seams in diameters of 30 in. and above. Under 30 in., lengths of 22 ft furnished without girth seam, or 40-ft lengths with one girth seam. Diameters range from 20 in. to 120 in.

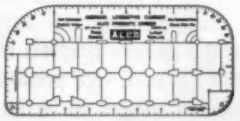
Use Alco Electric Welded Steel Pipe for your piping projects. Your nearest Alco Products Sales Representative will be happy to furnish you complete technical information and to discuss with you any special problems you may have.

Remember these Key features of Alco Steel Pipe:

STRONG • EFFICIENT • ECONOMICAL
DURABLE



PHILADELPHIA used efficient, durable Alco Electric Welded Steel Pipe in diameters of 60, 54 and 48 in., with thicknesses of ½ and ⅜ in. Sections are joined with Dresser couplings.



For information on how to obtain one of these handy Alco Piping Templates, write to your nearest Alco Products Sales Office.

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Sales Offices: New York, Chicago, Dunkirk, Los Angeles, Kansas City, Houston, Tulsa, Beaumont.

(Continued from page 36 P&R)

Woodie, all cast iron and a half-ton heavy, is the center of attraction of the accompanying pipers gathered to celebrate the 150th anniversary of R. D. Wood Co. in Philadelphia last November. Surrounding the still growing boy in the picture are, left to right: Theodore V. Wood, vice president and general sales manager of R. D. Wood Co.; Henry E. McWane, president of the Lynchburg Foundry Co.; N. F. S. Russell, board chairman, and C. S. Lawson, president, both of U.S. Pipe & Foundry Co.; John D. Capron, president of Glamorgan Pipe & Foundry Co.; and Otto Hodges, president of American Cast Iron Pipe Co. Also on hand, but apparently crowded out of the picture by those broad shoulders, were representatives of the Alabama Pipe Co., James B. Clow & Sons, Lone Star Steel Co., McWane Cast Iron Pipe Co., Pacific States Cast Iron Pipe Co., and Warren Foundry & Pipe Co., all prominent suppliers of cast-iron water pipe, which now has "served for more than a century" in 45 U.S. cities. Toasted at the testimonial dinner were Millville, N.J., birthplace of the Wood company in 1803, and Philadelphia, Pa., one of its first big customers for water pipe in 1816. Toasting with the rest of the cast, Woodie, as is his nature, it was said, carried his liquor best of all.

Standby power generators in the new "F" series of Wincharger Corp., Sioux City, Iowa, include as optional equipment line-transfer switches that automatically start the engines and apply their capacity of from 700 to 12,000 watts to the line.

(Continued on page 40 P&R)

1879—ROSS—1879

Automatic Valves

ALTITUDE VALVE

Controls elevation of water in tanks, basins and reservoirs

1. Single Acting
2. Double Acting

Maintains safe operating pressures for conduits, distribution and pump discharge

SURGE-RELIEF VALVE

REDUCING VALVE

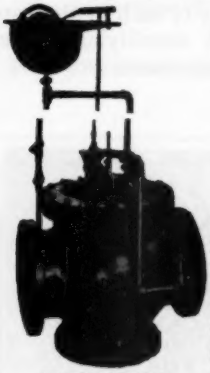
Maintains desired discharge pressure regardless of change in rate of flow

Regulates pressure in gravity and pump systems; between reservoirs and zones of different pressures, etc.

A self contained unit with three or more automatic controls

COMBINATION VALVE

Combination automatic control both directions through the valve.

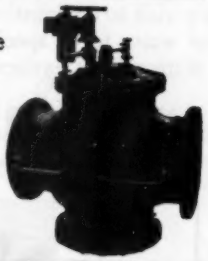


FLOAT VALVE

Maintains levels in tank, reservoir or basin

1. As direct acting
2. Pilot operated and with float traveling between two stops, for upper and lower limit of water elevation.

Electric remote control—solenoid or motor can be furnished



REMOTE CONTROL VALVE

Adapted for use as primary or secondary control on any of the hydraulically controlled or operated valves.

Packing Replacements for all Ross Valves Through Top of Valve

ROSS VALVE MFG. CO., INC., P. O. BOX 593, TROY, N.Y.

(*Continued from page 38 P&R*)

What price ice? really sounds appropriately Januaryish for our favorite question, although the current refrigeration actually began in the midst of New York's September heat wave. Then it was that the postal clerks union got all hot and bothered over the Post Office Department's alleged lackadaisical attitude toward the repair of the water refrigeration equipment that had broken down under the strain of a 90-degree September, leaving 8,000 postal workers with their tongues hanging out. To confuse this issue still further, local congressmen, more noted for hot air than ice, were called in "to end the water emergency and thus correct adverse physical conditions in the post offices." Meanwhile, in almost equally hot Toronto, meteorologists attending a Canadian-American conference were wistfully discussing the iceberg-milking technique used by their Arctic outposts to obtain fresh water supplies. And only a month later, ice water was an international issue again when it was publicly promoted by WCTU head Mrs. D. Leigh Colvin as the proper drink to serve King Paul and Queen Frederika of Greece on their visit to Chicago—iced Lake Michigan water to be specific.

With all this excitement, it was only proper, in November, to have someone do something about getting the ice to be more considerate of the water it chilled. This was Professor Edward W. Moore of Harvard, who, with a couple of his students, worked out a method of keeping ice cubes and crushed ice in a chlorine bath to eliminate the contamination proved to be present in a very large majority of ice samples collected in a survey of restaurants and hospitals. We, who have always considered an ounce of bourbon worth a pound of chlorine, may not consider this too happy an ending—which is not to argue the point that the price of ice should not be the danger of contamination.

The Somastic Div. of Bechtel Corp., which applies exterior protective coatings to steel pipe, has been sold to Pipe Linings, Inc. The latter organization is itself a subsidiary of American Pipe & Construction Co. and has lined the interiors of pipelines in place with cement mortar by the Centriline process for 13 years and by the Tate process for 4 years. The transfer was regarded as furthering the specialized interests of each of the parent companies, and simplifying procurement for their customers.

(*Continued on page 42 P&R*)

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NORTHROP & COMPANY, INC.
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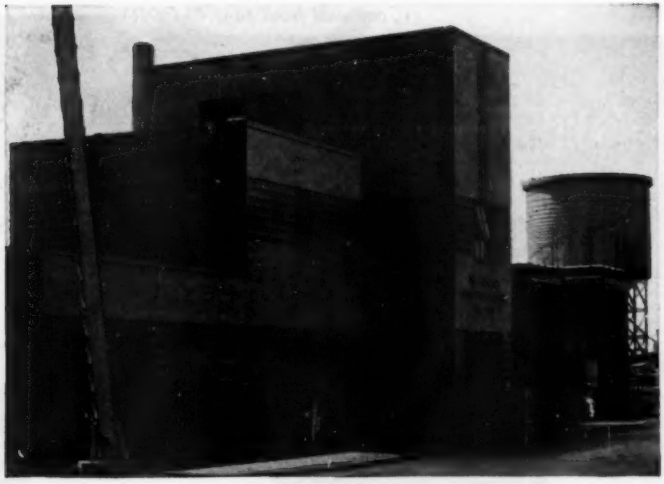


How Staples, Minnesota gets soft, clear water

Staples' well-water supply caused plenty of trouble . . . total hardness 275 ppm, alkalinity 200 ppm, iron 3 ppm, turbidity 30 ppm. To solve these problems, Staples turned to Water Conditioning Headquarters.

Now Mr. E. H. Klang, Supt. of the Water and Light Dept., reports the Permutit-treated water "very fine in all respects—very clear". Turbidity is reduced to only 3 ppm . . . iron to 0.1 ppm. Hardness and alkalinity are reduced to specifications.

Because of high Precipitator efficiency, each filter is backwashed only once a week for 20 minutes. "The Precipitator has not given any trouble. The Permutit filter is one of the best . . . has been trouble-free", adds Mr. Klang about this 1939 Permutit installation.

FREE TECHNICAL BULLETINS

Write today for full information on any water conditioning process or problem. The Permutit Company, Dept. JA-1, 330 West 42nd Street, New York 36, N. Y.

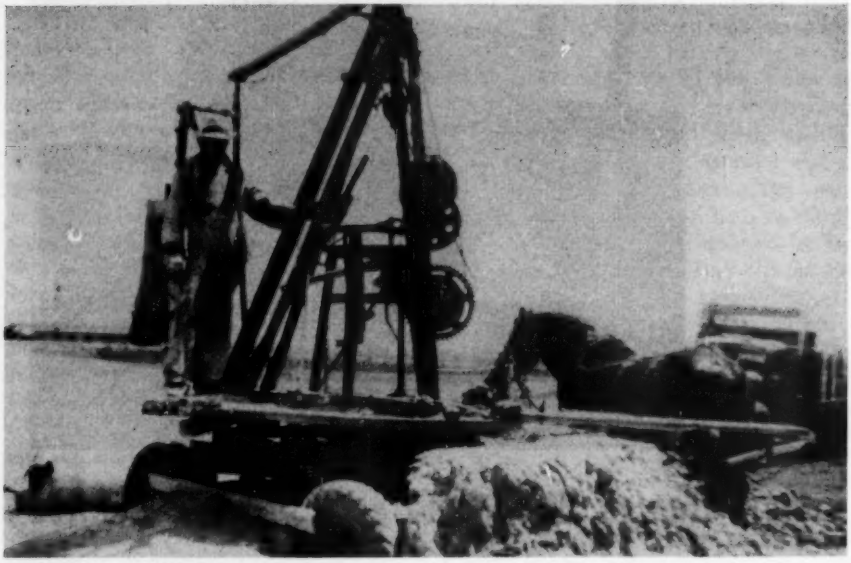
WATER CONDITIONING HEADQUARTERS FOR OVER 40 YEARS

PERMUTIT®

Staples' compact Permutit Precipitator has 400 gpm capacity. Softens hard well water, removes turbidity, iron, and manganese.

Two 8' x 9' Permutit Gravity Filters remove last traces of suspended matter, deliver a crystal-clear, softened water.

(Continued from page 40 P&R)

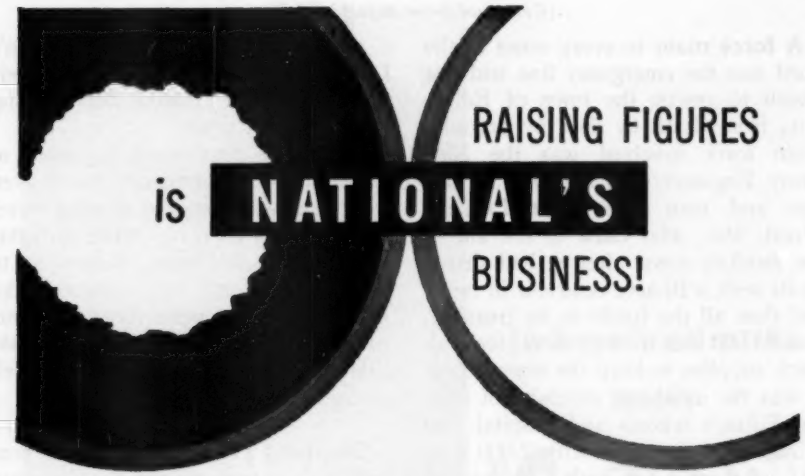


Strictly a one-horse operation is the well-drilling business owned by Ed Vadnais of Dallas, S.D.—one at a time, that is, for, in his 54 years in the business in Minnesota, Missouri, and, now, in South Dakota, Ed has actually worn out 38 previous equine partners in the business. Vital statistics of the accompanying picture of No. 39 turning the table note that the scene is Bonesteel, S.D., in the summer of 1953; the rig was acquired in 1913; the well being drilled was 80 ft deep; Ed. himself, astride the turntable, was 71 years old; and the prime mover rates exactly 1-hp. Not visible here, but prominent in the 30-minute movie that International Harvester has made of Ed in action, is the remote control feature of the operation—sonic rather than electronic, involving merely teamwork between boss and hoss.

Small-parts storage cabinets with plastic "See-Thru" drawers are being produced in a variety of sizes and combinations by General Industrial Co., 5738 N. Elston Ave., Chicago 30, Ill. One popular model, priced at $7.95 postpaid, contains 20 drawers $5\frac{7}{8} \times 2\frac{3}{4} \times 1\frac{7}{16}$ in. in a steel cabinet equipped with rubber feet. Adjustable dividers and drawer labels are also provided.

Two new drafting room gadgets have been introduced to speed work on the drawing board. The Krollometer, a plastic angle calculator with built-in spirit levels, may be used to convert angles to inches per foot of drop, carpenter square measurements, and grade percentages. It is available from Christensen & Kroll, Box 284, McMinnville, Ore. The Paraline, a device for scaling parallels which also serves as protractor, scale, and straight edge, is available in two models, the Professional ($12\frac{1}{2} \times 3\frac{1}{2}$ in.) at $5.50, and the Standard ($10\frac{1}{2} \times 3\frac{3}{16}$ in.) at $3.95—from Pickett & Eckel, Inc., Chicago 3, Ill.

(Continued on page 44 P&R)



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During that period, we've cleaned over 45,000,000 feet of cast iron water mains and, we have yet to find the main (regardless of age or condition) that National can't restore to at least 95% of its original rated capacity.

The cost of National cleaning is small, compared to the advantages and savings effected in increased volume and reduced pumping costs. Resultant increase in water pressure reduces fire hazard, particularly in outlying districts.

At no obligation to you, our engineers will check the condition of your water mains, and if they need cleaning, estimate the cost of *National cleaning.*

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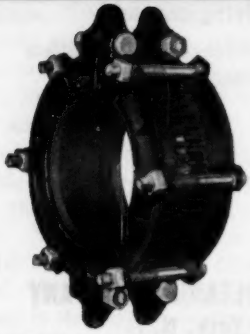
(*Continued from page 42 P&R*)

A force main in every sense of the word was the emergency line laid last month to rescue the town of Edina, Mo., from death by debt by drought. Main force involved was the 33rd Army Engineer company of 156 officers and men from Fort Leonard Wood, Mo., who came to the aid of the stricken town after it had drunk up its well, a 10-acre reservoir in town, and then all the funds in its treasury, plus $3,000 that weren't there, for tank truck supplies to keep the town going. It was the imminent necessity of closing Edina's schools and hospital that brought the Army in with 2,000 tons of 6-in. combat line and 3 pumps and generators to force along a reservoirful from an 80-acre lake 4.8 miles distant. And it was just 54 hours of round-the-clock work later that the pumps began their two-week operation of delivering a winter's supply, while the town's 1,700 turned out in force to give their rescuers proper thanks for making Edryna Edina again.

Indications that what happened at Edina might be dynamite came even before the water started flowing there, when officials from two other drought-stricken Missouri towns showed up to file applications for similar help. Which will, of course, force the issue and eventually establish: Forces, task, Engineer, use of, proper, for relief, emergency, of civilians.

Sheppard T. Powell, Baltimore consultant, has been elected to Honorary Membership in the American Society of Mechanical Engineers. The presentation was made at the ASME annual banquet in New York on December 2nd.

FOR REPAIRING BROKEN MAINS



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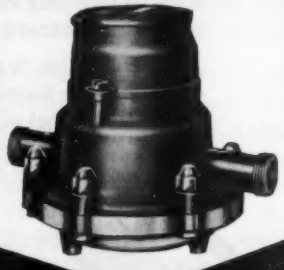

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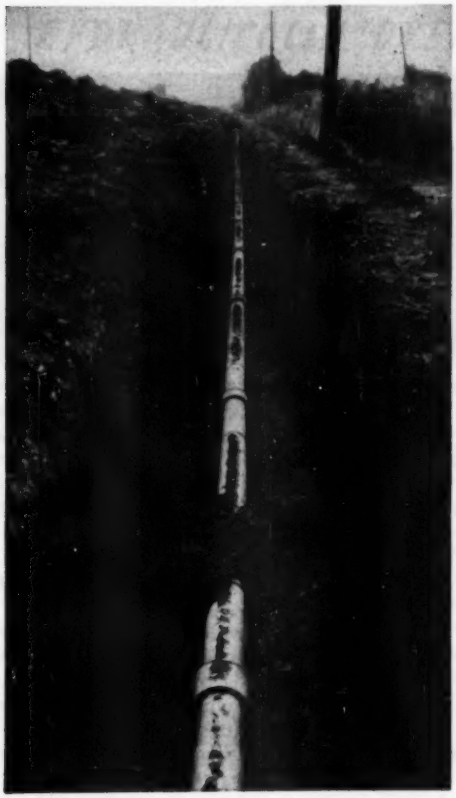

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Insect, Fungus, and Weed Control. *E. R. de Ong. Chemical Publishing Co., 212—5th Ave., New York 10, N.Y. (1953) 400 pp.; $10*

This systematic survey of chemicals for the control of insect and plant pests will be of primary interest to those water works men who are responsible for watershed and reservoir areas. It will also appeal, however, to those whose responsibility for water quality has made them conscious of the possible hazards resulting from the wholesale use of such compounds as DDT, chlorinated camphene, gamma benzene hexachloride, 2,4-D, lindane, chlordane, and other wonder-workers. In this connection, the somewhat limited discussion of the toxicity of the compounds to man and to livestock will be helpful.

Vegetation and Watershed Management: *An appraisal of vegetation management in relation to water supply, flood control, and soil erosion. E. A. Colman. Ronald Press Co., 15 E. 26th St., New York 10, N.Y. (1953) 412 pp.; $7.00*

This carefully documented, scholarly study was sponsored by the Conservation Foundation, which is interested in both sides of the equation relating vegetation management to water supply and control. Even with his interest concentrated in the latter element of the equation, the water works man will find this book a major contribution to the science of watershed management, both in presenting such facts as are known and in pointing to the areas of uncertainty that should be resolved. But perhaps even more important than the specific information imparted by this book is the stress the author places on the slowness with which many clearly defined processes can work, either to the detriment or the benefit of the water supply. The benefits to be obtained from proper logging practices; the damage done by overgrazing—such effects can be so long in the making that improper policies can be followed for years, until the damage is at once evident and irreparable. It is clear that education is as great a need as research, but, for either purpose, this book provides a sound and worthwhile foundation.

Public Grounds Maintenance Handbook. *H. S. Conover. Tennessee Valley Authority, Div. of Reservoir Properties, Old Post Office Bldg., Knoxville, Tenn. (1953) 495 pp.; paperbound; $5*

This hefty volume collects in one bulky but well organized place a mass of TVA-tested information on groundskeeping and landscaping that with some modification can be useful to any water utility that has a watershed area to keep up, to say nothing of the grounds around its various buildings, stations, tanks, and other facilities. When such grounds are extensive enough to warrant systematic care and cultivation, the use of this book can be highly recommended—allowing of course for climatic differences. It appears to be an ideal one-volume reference work, and on most subjects will be found to contain too much rather than too little information. Generous use of illustrations adds to the value of the sections on grasses, weeds, and insect pests, and detail drawings provide a useful supplement—if somewhat narrower in scope—to the sections on roads and parking and picnic areas.

(Continued on page 48 P&R)

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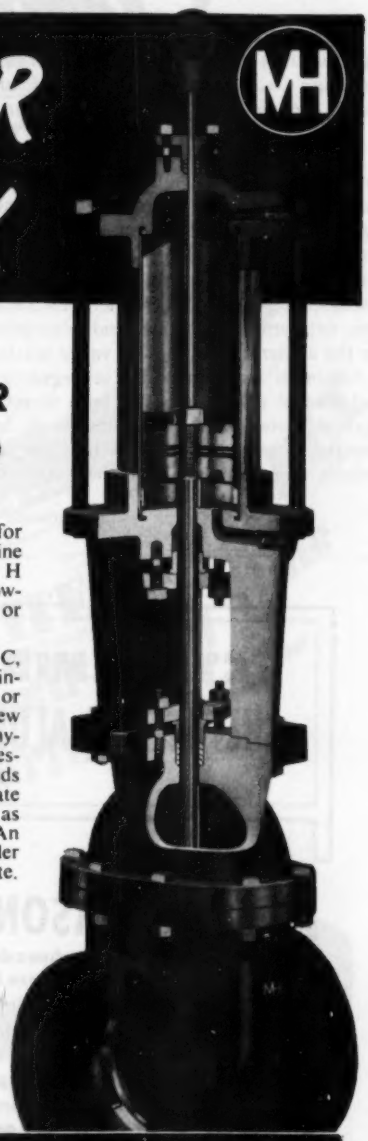

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The Reading Meter

(Continued from page 46 P&R)

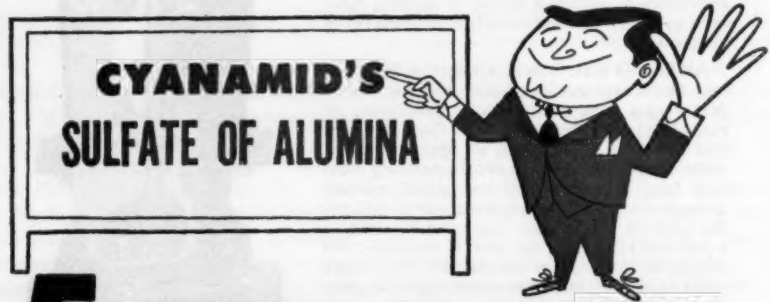
Gas and Vapor Abatement. *Chap. 10, Air Pollution Abatement Manual. Manufacturing Chemists' Assn., 246 Woodward Bldg., 15th & H Sts., N.W., Washington 5, D.C. (1953) 29 pp.; paperbound; 60¢*

Issued in booklet form chapter by chapter, this manual is a constructive contribution toward the ultimate goal of taking the waste nuisance out of industrial processes. The present section, by R. J. Jenny of the American Cyanamid Co., discusses absorbers or scrubbers, incineration, catalytic combustion, and adsorption for the abatement of gas and vapor wastes.

Although most attempts at regulation and control until now have been directed against waterborne pollutants, it is becoming increasingly evident that the air pollution problem can stir the public up to a much greater degree. The water treatment plant stands between the polluted stream and the public, so that only those in search of recreation or with an active interest in the technical and financial aspects of water supply are directly affected by polluted waters. But air must be breathed directly, and the recent blanket of smog or "smaze" that plagued the entire Northeast proved how quickly the public notices—and resents—atmospheric contaminants.

A price list of other sections of the manual may be obtained from the publisher, at the address given above. Among chapter titles of general interest are "Community Relations" (25¢), "Legislative Requirements" (30¢), and "Physiological Effects" (60¢).

(Continued on page 50 P&R)



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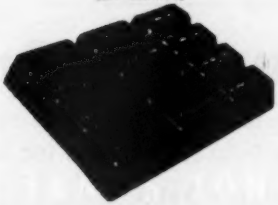

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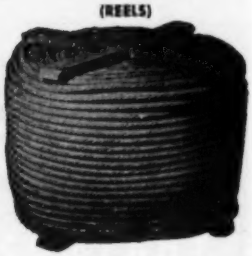

HYDRAULIC DEVELOPMENT CORPORATION

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(Continued from page 48 P&R)

Hydraulic Research in the United States. *Helen K. Middleton & Sonya W. Matchett, ed. Misc. Pub. 208, National Bureau of Standards, Washington 25, D.C. (1953) 203 pp.; paperbound; $1.25 from Government Printing Office, Washington 25, D.C.*

This survey of hydraulic research being conducted at various laboratories and institutions has become an annual feature. In addition to detailing the title of the project, its sponsor, and where and by whom it is being conducted, the report notes the nature of the investigation and gives a brief description of the project, its present status, and any results and publications produced.

Proceedings of the Second Annual Symposium on Water Conservation and Industrial Development, Nov. 19–20, 1952. *Bul. 38, Engineering Experiment Sta., Louisiana State Univ., Baton Rouge 3, La. (1953) 86 pp.; paperbound; 50¢*

The papers collected in this bulletin include studies on water conservation in the kraft pulp and paper, the petroleum, and the sugar industries; the waste-assimilating capacity of natural waters; the industrial development of Louisiana's river basins; and the influence of water resources and waste disposal facilities on plant location.

Final Report on Field Investigation and Research on Waste Water Reclamation and Utilization in Relation to Underground Water Pollution. *Univ. of California Sanitary Engineering Research Project. Pub. 6, State Water Pollution Control Board, Rm. 610, 721 Capitol Ave., Sacramento 14, Calif. (1953) 124 pp.; paperbound; free*

This study of ground water recharge through spreading of sewage effluents was conducted very carefully, and produced some highly interesting conclusions. In addition to determining that a high degree of sewage treatment is necessary if the effluent is to be spread efficiently, and offering suggestions for the "conditioning" of the soil, both initially and at six-month intervals thereafter, the study offers evidence that the practice of spreading can be bacteriologically safe. In addition, chemical contamination of underground supplies can be avoided if the content of industrial wastes in the raw sewage is limited. The report also cautions that two other nuisances besides pollution must be guarded against: the spreading pond can be responsible for mosquitoes and possible algal odors.

(Continued on page 52 P&R)

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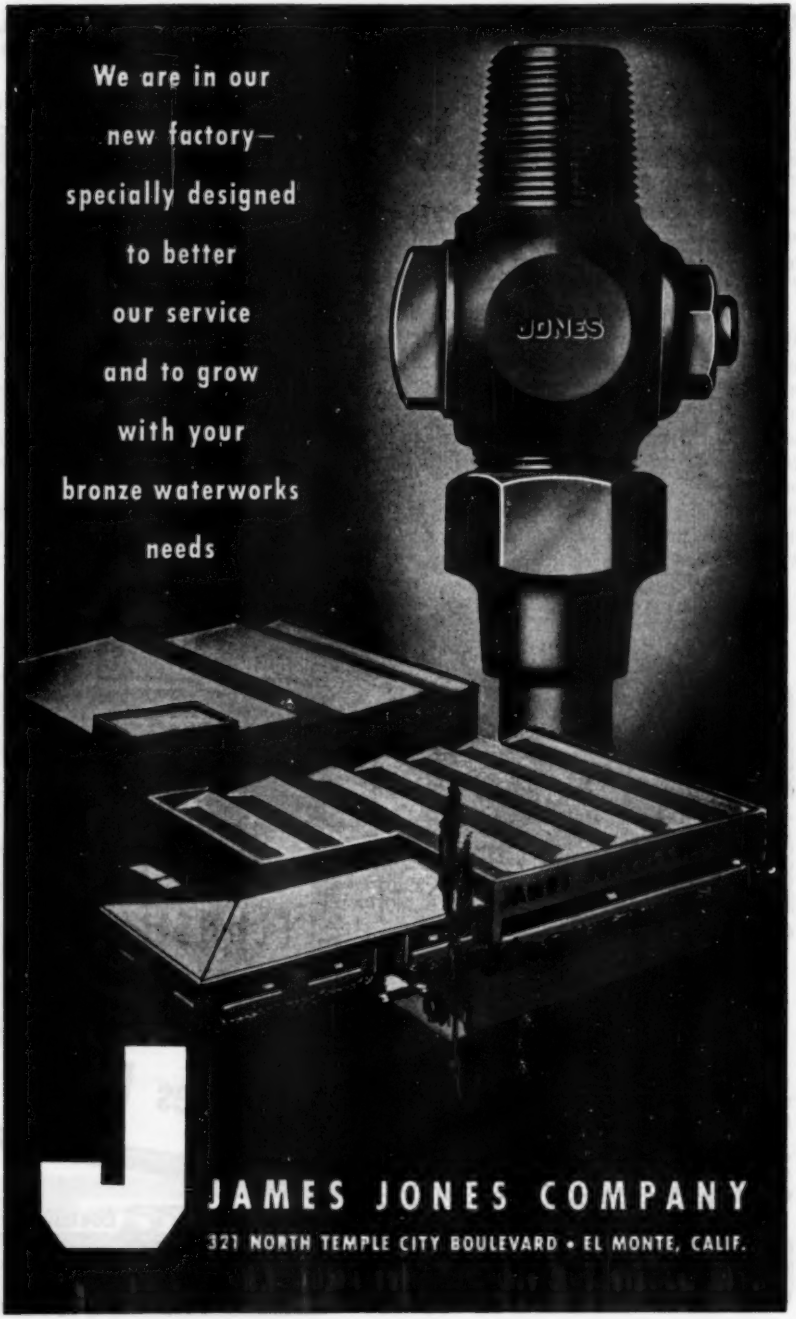
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The Reading Meter

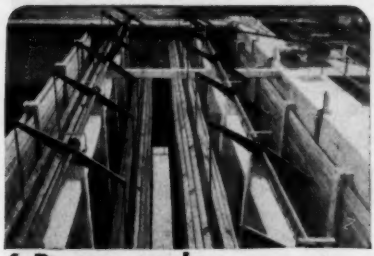
(Continued from page 50 P&R)

Suggested Post-Attack Production Measures. *Office of Defense Mobilization, Executive Office of the President, Washington 25, D.C. (1953) 9 pp.; paperbound; free from Water and Sewerage Industry and Utilities Div., Business and Defense Services Administration, Dept. of Commerce, Washington 25, D.C.*

This pamphlet might well be subtitled "Be Prepared." It offers an outline to guide management's thinking on the best means to reduce the extent of damage from industrial bombings or other attacks before they occur, to offset their disruptive effect by providing alternative sources of supply, and to minimize their aftereffects by planning reconstruction in advance of need. The emphasis is on looking ahead; industry itself will have provided the actual means. Problem for homework: what would *you* do if your main pumping plant were bombed out? if your reservoir were hopelessly contaminated by radioactivity? if your boss (or, what amounts to the same thing, the public) asked what plans you are making against these contingencies?

Ground Water for Irrigation in Box, Butte County, Nebraska. *Raymond L. Nace. With a Section on the Chemical Quality of the Water by W. H. Durum. Circular 166, Geological Survey, Washington 25, D.C. (1953) 39 pp.; paperbound; free*

This study was conducted as part of the Interior Department's program for Missouri River Basin development.



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Balmer, Robert Ray, Supervisor, Water Waste & Weather Group, Eng. Dept., E. I. du Pont de Nemours & Co., Wilmington 98, Del. (Oct. '53)

Barber, Louis, Pres., Barber Bridge Drilling Corp., 3020 Empire Ave., Burbank, Calif. (Oct. '53)

Bauer, Robert O., Eng. Inspector, Bureau of Water, 4826 N. 13th St., Philadelphia 41, Pa. (Oct. '53)

Bock, W.; *see* Geological Center

Boyce, William N., Second Vice-Pres., Boyce Co., Inc., Box 968, Clearwater, Fla. (Oct. '53)

Boyd, James J., Pres. & Designing Engr., Remington & Boyd, 503 Market St., Camden, N.J. (Oct. '53)

Brewer, Robert, Dist. Engr., State Health Dept., 1446 N. 9th St., Colton, Calif.

Briggs, Henry C., Asst. San. Engr., Ind. State Board of Health, 1330 W. Michigan St., Indianapolis 7, Ind. (Oct. '53)

Brown, Linas H., Chief of Munic. Dept., De Leuw, Cather & Co., 150 N. Wacker Dr., Chicago 6, Ill. (Oct. '53)

Carlson, Clarence L., Sales Engr., W. P. Nevins Co., 53 W. Jackson Blvd., Chicago 4, Ill. (Oct. '53)

Chandler, R. C.; *see* Martha Mills

Corp. M. R., Supt., Dept. of Public Works, Marcellus, N.Y. (Oct. '53)

County Water Systems, Inc., Alton C. Melville, Vice-Pres., 501 First Security Bank Bldg., Salt Lake City, Utah (Corp. M. Oct. '53)

Crase, George H., Jr., Contracting Engr., Horton Steel Works Ltd., 205 Insurance Exchange Bldg., Calgary, Alta. (Oct. '53)

Craven, Warren S., Eng. Asst., Office of City Engr., 1437 N.E. 16th Ave., Ft. Lauderdale, Fla. (Oct. '53)

Crossman, G. F., Jr., Field Engr., Fischer & Porter—Canada, Ltd., Beverley Hills, Ont. (Oct. '53)

Decker, Charles G., Assoc. Prof. of Civ. Eng., Texas Technological College, Dept. of Civ. Eng., Lubbock, Tex. (Oct. '53)

Dodson, Lewis, Engr., Box 287, Amarillo, Tex. (Oct. '53)

Dohaney, V. C., Sr. San. Engr., Dept. National Health & Welfare, Box 86, Moncton, N.B. (Oct. '53)

Drexel Inst. of Technology, Ranald V. Giles, Prof. of Civil Eng., 32nd & Chestnut Sts., Philadelphia 4, Pa. (Corp. M. Oct. '53)

Dwiggins, Gordon L., Supt., E. B. Bain Filter Plant, 2330 Bernard St., Raleigh, N.C. (Oct. '53)

Eisenberg, William F., Mech. Engr., Water Dept., 425 Mason St., San Francisco 2, Calif. (Oct. '53)

Ernst, T. Edward, Cons. Engr., 822 Perdido St., New Orleans 12, La. (Oct. '53)

Evans, Robert B., Sr. Engr., Ford, Bacon & Davis, Inc., Apt. F-31, 201 Abbott Rd., Radburn, Fair Lawn, N.J. (Oct. '53)

Faust, Samuel D.; *see* Taylor, W. A., & Co.

Fencl, Ernest, Supt., Water Dept., Box 226, Soap Lake, Wash. (Oct. '53)

Fischer, George F., Meter Repr., Neptune Meter Co., 6306 S.E. 36th, Portland, Ore. (Oct. '53)

Folendorf, Ernest B., Engr. of Distr., Calif. Water Service Co., 374 W. Santa Clara St., San Jose, Calif. (Oct. '53)

Gentry, George G., Asst. San. Engr., State Dept. of Public Health, 334 Rowell Bldg., Fresno, Calif. (Oct. '53)

Geoldner, Richard, Chem. Engr., Cleaver Brooks Co., 4572 N. 23rd St., Milwaukee 9, Wis. (Oct. '53)

Geological Center, W. Bock, 1900 Arch St., Philadelphia, Pa. (Corp. M. Oct. '53)

Gibson, Desha, Acting Supt., Water Works, Bedford, Ind. (Oct. '53)

Giles, Ranald V.; *see* Drexel Inst. of Technology

Grant, Nye, Uhlmann & Assocs., 1441 N. High St., Columbus 1, Ohio (Oct. '53)

Harris, Pratt M., Repr., U.S. Pipe & Foundry Co., 405 Frick Bldg., Pittsburgh 19, Pa. (Oct. '53)

Hawkins, Derick; *see* Kitimat (B.C.)

Hawkins, Edgar M., Jr., Mgr., Water, Gas & Elec. Dept., Danville, Va. (Oct. '53)

Hawkins, Maurice B., Supervising Sanitarian, Riverside County Health Dept., 8595 Fox Ave., Arlington, Calif. (Oct. '53)

Haynes, Hanford, Pacific Northwest Sales Mgr., Consolidated Western Steel Div., 1729 Exchange Bldg., Seattle 4, Wash. (Oct. '53)

Hoff, Ernest E., Asst. Engr., San Francisco Water Dept., 2578—46th Ave., San Francisco, Calif. (Oct. '53)

Johnston, C. A., Supt., Water Dept., Box 350, Salem, Va. (Oct. '53)

Keating, Thomas F., Estimating Engr., De Laval Steam Turbine Co., Nottingham Way, Trenton, N.J. (Oct. '53)

Kitimat, Corp. of Dist. of, Derick Hawkins, Works Supt., Box 380, Kitimat, B.C. (Munic. Sv. Sub. Oct. '53)

Kohlmeier, Richard W., Jr., North Dade Elec. Co., 853 N.E. 125th St., N. Miami, Fla. (Oct. '53)

Layne, Mark B., Cons. Engr., Higginsville, Mo. (Oct. '53)

Layton, Raymond E., Cons. Engr., 1011 McKeever Court, Hayward, Calif. (Oct. '53)

Leaf, Robert L., Mgr., Leighton Supply Co., 1224–36 First Ave., S., Fort Dodge, Iowa (Oct. '53)

Liebmann Breweries, Inc., Gerard McNeil, Lab., 36 Forrest St., Brooklyn 6, N.Y. (Corp. M. Oct. '53)

MacLeman, Everett L., Asst. Prof., Yale Univ., Winchester Hall, 15 Prospect St., New Haven 11, Conn. (Oct. '53)

Martha Mills, Div. of B. F. Goodrich Co., R. C. Chandler, Plant Engr., Thomaston, Ga. (Corp. M. Oct. '53)

Matherly, Bernard, Water Supt., 632 Main St., Grinnell, Iowa (Oct. '53)

McNeil, Gerard; *see* Liebmann Breweries, Inc.

McWilliams, Curtis Q., Asst. Mgr., Roaring Creek Water Co., 204 E. Sunbury St., Shamokin, Pa. (Oct. '53)

McWilliams, Douglas E., Jr., Asst. Mgr., Roaring Creek Water Co., Shamokin, Pa. (Oct. '53)

Melville, Alton C.; *see* (Salt Lake City) County Water Systems, Inc. (Oct. '53)

Moedlhammer, Franz, Con. Director, American Katadyn Corp., 375 Fairfield Ave., Stamford, Conn. (Oct. '53)

Montoto, Carlos Ernesto, Jr. Engr., Johns Manville International Corp., Calle Cuba 64, Dpto. 303, Havana, Cuba (Oct. '53)

Morris, E. L., Mgr., Radnor Water Dist., 2229 Nolensville Rd., Nashville, Tenn. (Oct. '53)

Murphy, J. G., Dist. Mgr., Worthington Corp., 5075 Santa Fe Ave., Los Angeles 58, Calif.

Naylor, Frank, Filter Plant Operator, Board of Water Comnrs., Frost Lane, Peekskill, N.Y. (Oct. '53)

Pedroso, Eduaro Brunet, Galiano 257, Havana, Cuba (Oct. '53)

Pennsylvania Salt Mfg. Co. of Washington, Brian L. Shera, Mgr., Tech. Service Dept., 2901 Taylor Way, Tacoma, Wash. (Assoc. M. Oct. '53)

Plee, Leonard S., Supervisor, Research & Statistics, State Public Service Com., Lansing 13, Mich. (Oct. '53)

Powers, F. Allan, Sales Engr., W. P. Nevins Co., 53 W. Jackson Blvd., Chicago 4, Ill. (Oct. '53)

Rice, Dan R., Foreman of Distr., Water Dept., 3414 Austin St., Corpus Christi, Tex. (Oct. '53)

Rush, Jack B., Supt., Water Dept., 1600 Floribunda Ave., Hillsborough, Calif. (Oct. '53)

Sasso, Francis A., Sales Engr., W. P. Nevins Co., 53 W. Jackson Blvd., Chicago 4, Ill. (Oct. '53)

Shera, Brian L.; *see* Pennsylvania Salt Mfg. Co. of Washington

Stout, Charles R., Well Field Supervisor, Ottawa St. Pumping Station, Dayton, Ohio (Oct. '53)

Taylor, W. A., & Co., Samuel D. Faust, Chemist, 7300 York Rd., Baltimore 4, Md. (Assoc. M. Oct. '53)

Todd, John W., Pres., Hill Country Waterworks Co., 404 Frost Natl. Bank Bldg., San Antonio, Tex. (Oct. '53)

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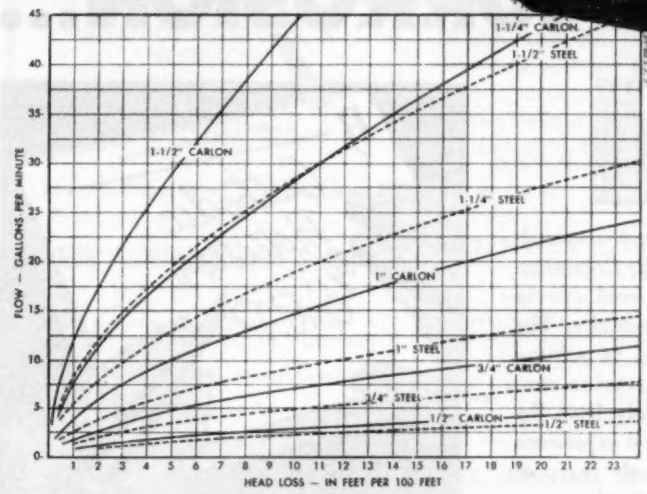

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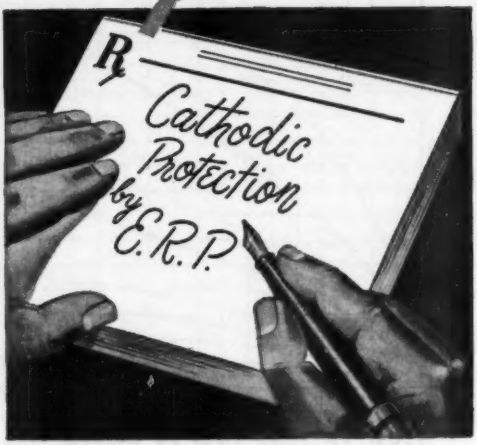

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Key: In the reference to the publication in which the abstracted article appears, **39**:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, **39**:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *BH—Bulletin of Hygiene (Great Britain); CA—Chemical Abstracts; Corr.—Corrosion; IM—Institute of Metals (Great Britain); PHEA—Public Health Engineering Abstracts; SIW—Sewage and Industrial Wastes; WPA—Water Pollution Abstracts (Great Britain).*

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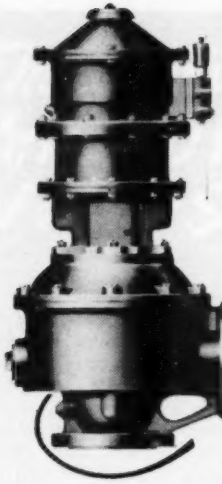
Modern Instrumentation Devices in British Water Works. L. WALTER. Munic. Util. (Can.), **90**:7:30 (Jul. '52). Distance over which remote indication of water level and of pump operation can be obtained now practically unlimited. Latest development is graphic control panel by which whole plant not only can be supervised from central control room, but can also be automatically controlled. Several typical British instrument designs described, with examples of practical applications, including Evershed "Noflote" control for "cascade pumping," operation of variable-speed pumps, and maintenance of water level in storage tanks. Device consists of 2 level rods or electrodes, adjustable in length, and special relay connected to pilot coil of motor starter. Liquid completes elec. circuit through electrodes and, when cycle of operation completed, relay resets itself automatically. Also described is Elliott electronic system for remote indication and control of water level, and Elliott-Shotter systems for local supervision of deep well pumping and for fully automatic remote control.—*R. E. Thompson*

Practical Application of Applied Geophysics to Utility Operations. G. M. MACLEOD. Munic. Util. (Can.), **91**:3:17 (Mar. '53). "M-Scope Pipefinder" may be used to det. location and depth of single pipe; trace given pipe through maze of adjacent pipes; detect buried power conduits; locate valve boxes, abandoned wells, and isolated metal objects; and check path of proposed excavations. App. consists of portable radio transmitter and radio-direction-finder type receiver. Former induces electromagnetic field in buried object which is detected by receiver, with accompanying buzzing in earphones and deflection of meter. Practical depth range 15'–20'. By connecting transmitter to pipe, latter can be traced through maze of other pipes. Can be used with min. of interpretational difficulties even by novice operators. Approx. 30,000 such instruments in use.—*R. E. Thompson*

Demonstration of the "Aqua-Visual" Apparatus for Leak Detection at Sheffield. ANON. Wtr. & Wtr. Eng. (Br.), **57**:197 (May '53). App. consists essentially of vibration pickup, of which signals are amplified and made measurable. Sensitive microphone is acoustically insulated from street noises. Although vibrations produced by leakage are easily transmitted and measurable through all normal sizes of pipes, transmission is not so good when pipelines of large diam. are concerned. Upon test, instrument appeared to be of greatest value in demonstrating leak where there were number of contact points, but was not efficient in locating precise point of leak.—*H. E. Babbitt*

Analysis of Water Supply Reticulation. Part I. W. L. HURD. Commonwealth Engr. (Australia), **40**:55 (Sept. 1, '52). Author discusses problem of planning reticulation of town water supply to provide adequate and continuous supply to all users. After review of problem he gives statement of supply position at Wagga Wagga, in New South Wales. Demand, taking into consideration future expansion, was taken at 2 gpm per tenement. Author establishes theoretical basis of calculations and then applies theory to practical problem existing at Wagga Wagga, giving fully worked out example. To simplify calculations, author developed "ready reckoner." Author concludes that, although reticulation flow analysis appears at outset to be lengthy and involved process, procedure can be employed by junior staff members once methods have been mastered. In due course, process becomes almost mechanical but that does not deprive it of element of fascination. Once ready reckoner has been developed, it

(*Continued on page 64*)



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(*Continued from page 62*)

may be utilized for any reticulation system. —*PHEA*

How the Problem of Moving a 1,900-Ton Water Tower Was Solved. ANON. Munic. Util. (Can.), 91:3:23 (Mar. '53). Concrete water tower, 80′ high, in Bedford Rural Dist., England, moved 300 yd to new site at cost about half that of constructing new one. Caterpillar diesel tractor with 10:1 block-and-tackle reduction used to pull structure on cradle over concrete-based track. Latter consisted of continuous ball races made up of bullhead section railway lines laid on their sides one above other, between which were approx. 800 steel balls, 2.5″ in diam. Four ball races arranged in pairs, each pair supported by line of precast concrete blocks, 6′ wide at bottom and 2′ at top, which spread load over 2 concrete roads built for purpose. First section of track built up around and through 2′ concrete walls of tower. Concrete cradle made up of prestressed 6′ × 2′ concrete beams. Where these went through tower structure, only holes for prestressed cable were bored through, so that tower formed part of cradle. 8 of tower's 12 supporting columns and panel walls cut away by blasting, and remaining 4 columns then gradually cut away until tower settled on track. Tower moved approx. 50′ in each haul, blocks, track and ball races then being moved from rear to front for next haul. Moving accomplished in 4 weeks.—*R. E. Thompson*

The Effect of Chlorination of Drinking Water on Brass Fittings. Resume of Research Reports No. 4, 5. C. A. RISBRIDGER. J. Inst. Wtr. Engrs. (Br.), 6:65 (Feb. '51). Test was devised to create conditions resembling those to which seats of ball valves are subjected. Method used was to force water at high velocity through nozzle of ⅛″ bore, similar in shape to that found in standard ½″ high-pressure ball valve; but, instead of water impinging on rubber washer, it was made to impinge on polished brass

(*Continued on page 66*)

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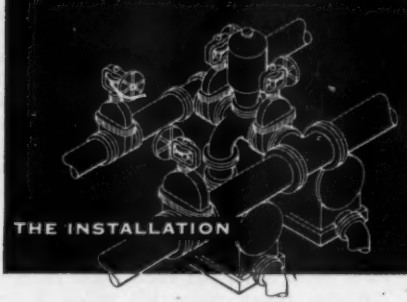

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(Continued from page 64)

disk of same composition as nozzle. Gap was maintained at $\frac{1}{8}$" and pressure at 40 psi. Nozzles and disks were made from sand-cast brass of following composition: Cu, 7.74%; Sn, 1.75; Pb, 2.20; Fe, 0.21; Al, not detected; Zn, balance. Analysis of tap water was: free Cl_2, 0.2 ppm; free CO_2, 3.08 ppm; DO, 7.2 ppm; chlorides, 51 ppm; sulfates, 165 ppm; temporary hardness, 8.0 ppm; permanent hardness, 218 ppm; pH, 7.6. It was concluded that: [1] cast brass, when subjected to action of distilled water at high pressure and velocity under conditions described, forms hard protective film and undergoes negligible attack; [2] using Doncaster tap water containing 0.2 ppm free chlorine, film formation does occur and very slight attack takes place; [3] addition of extra free chlorine to tap water renders surface film powdery and nonadherent; increased attack takes place with 0.6 ppm free chlorine, and severe attack with 1.0 ppm free chlorine.. Research Report No. 5 covers test using better control of chlorine dose and hot stamping brass, with and without addition of tin, as well as cast brass. Quantitative measure of corrosion was made by weighing disk specimens before and after test. It was concluded that corrosive action of Doncaster tap water at high pressure and velocity on both cast brass and hot stamping brass is greatly accelerated by presence of free dissolved chlorine in amounts up to 1 ppm. Under identical conditions and using tap water containing 1 ppm free chlorine, cast brass and hot stamping brass undergo similar losses in weight, but attack on latter is generally smooth and even, whereas that on cast brass results in more damaging form of irregular pitting. Addition of 1% tin to hot stamping brass does not confer increased resistance to attack by dissolved chlorine under these conditions. Results suggest that presence of Al may be beneficial. Increasing gap between nozzle and disk, which corresponds to opening ball valve more fully, has little effect on total corrosion taking place, but makes it less localized in character.—*H. E. Babbitt*

(Continued on page 68)

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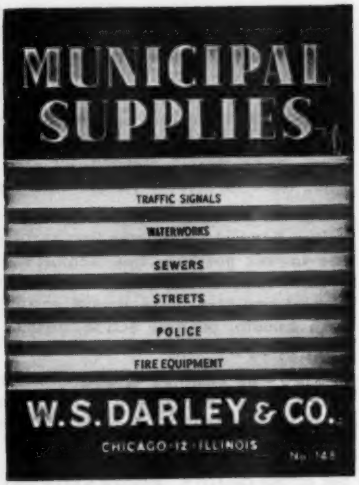

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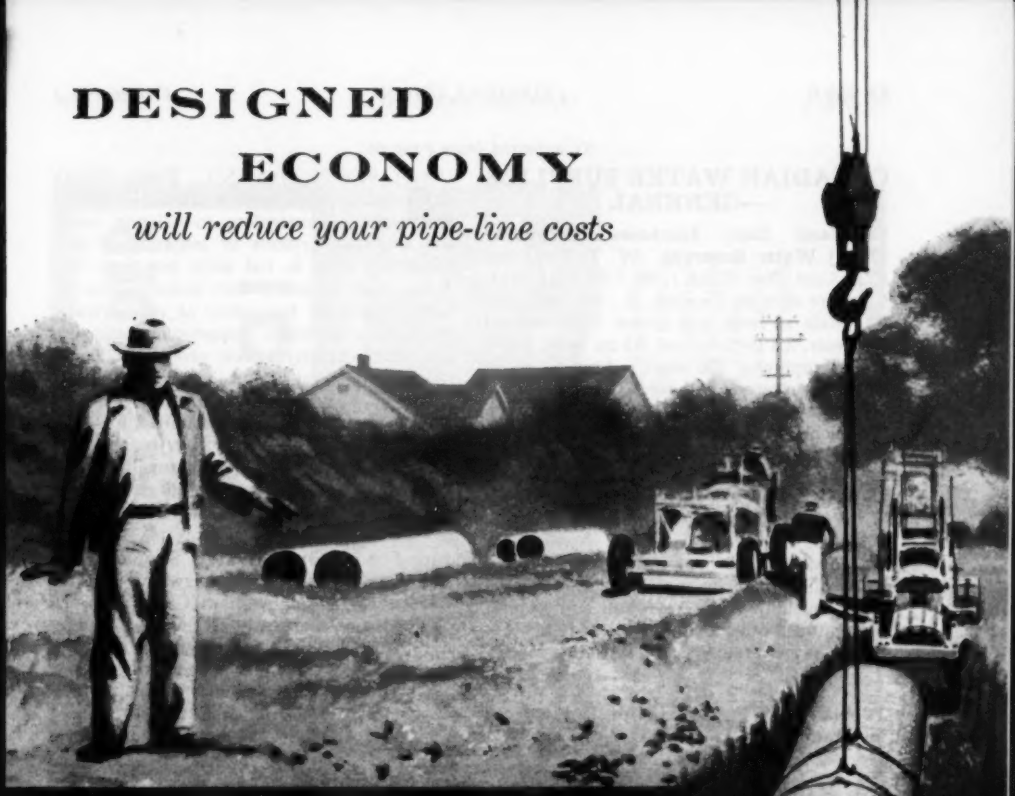

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(Continued from page 66)

CANADIAN WATER SUPPLIES —GENERAL

Cleveland Dam Increases Vancouver [B.C.] Water Reserves. W. T. FUNSTON. Eng. Cont. Rec. (Can.), **66**:7:88 (Jul. '53). Concrete dam on Capilano R., 325′ high and 640′ wide at crest, will create 16,500-mil gal reservoir, 3.5 mi long and 0.5 mi wide, capable of supplying 200 mgd. Area of about 550 acres cleared: 180 acres "close cut" and remainder grubbed. Water will flow through 90″ tunnel over ¾ mi long under harbor and thence through 70″ main into system. Turbine pumps will deliver to tanks or reservoir in north and west Vancouver: also, sufficient power will be generated to actuate equip. at dam site. Greater Vancouver Water Dist., 675 sq mi, 672,000 pop., includes 4 cities and 12 smaller municipalities. Supply, entirely from 4 mountain sources, is soft and requires no treatment other than intermittent chlorination. Water rates, 7.5¢/1,000 gal.—*R. E. Thompson*

Problems of Public Health Engineering in Manitoba. L. A. KAY. Munic. Util. (Can.), **91**:6:25 (Jun. '53). Public Health Act requires ministerial approval of addns., alterations, or extensions to existing water and sewerage systems or initiation of new projects. This is not very practical, and it has been proposed that municipalities be held responsible for safety of public water supplies, with health department acting in consultant capacity. New projects will still require approval. Labs. maintained for chem., phys., and bact. examns. and for pilot plant tests. All samples submitted for bact. examn. screened for high NO_3 content. 31 communities served by public supplies, some with modern purif. plants. High costs deterring new installations.—*R. E. Thompson*

Jurisdiction Over Water Supplies and Sewerage in New Brunswick. A. J. CAMERON. Munic. Util. (Can.), **91**:7:26 (Jul. '53). Municipalities required to submit plans, specifications, engineers' reports, and ests. for proposed systems to minister for approval. Minister may order changes or addns. to any system that may be menace to health. No serious outbreaks of water-

(Continued on page 70)

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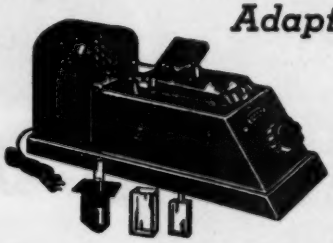
Adaptable for Use in Water Analysis



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AMERICA'S LARGEST MANUFACTURER OF PIPE CLEANING TOOLS AND EQUIPMENT

(*Continued from page 68*)

borne disease since Dept. of Health established in '18. Survey of F content of all supplies being made. No supply fluoridated. —*R. E. Thompson*

Design of Filtration Plant at New Toronto [Ont.] Affected by Space Limitation. R. W. ANGUS. Munic. Util. (Can.), **91**:6:28 (Jun. '53). Pressure filter plant overloaded. New 15-mgd modern rapid sand plant approaching completion. Intake pipe, 42" steel, extends 1,800' into L. Ontario and terminates in concrete crib with openings 26' below mean water level. Plant includes suction well with fine screens, alum feeders, and chlorinators; mixing chambers, equipped with flocculators, providing 33-min detention; settling basins providing 3-hr detention; 6 2.5-mgd filters, divided into 2 halves to facilitate washing; and clear well. Wash water pumps provide min. vertical backwash water rise of 24"/min, and fixed-surface wash system is included. Both low- and high-lift pumping stations equipped with 2 5-mgd and 2 2.5-mgd pumps, all motor driven.—*R. E. Thompson*

Water Supply and Sewerage to Be Under Unified Control in Greater Toronto [Ont.]. ANON. Munic. Util. (Can.), **91**:2:15 (Feb. '53). Bill introduced in Ontario legislature provides for federation for certain purposes of 13 municipalities in Toronto area, other powers of local municipalities being continued. Federation to be known as Metropolitan Toronto, and its council will consist of heads of councils of all member municipalities, 2 members of board of control, and 9 aldermen from Toronto. Chairman to be appointed by lieutenant-governor-in-council in '53–'54 and thereafter elected by metropolitan council. Metropolitan municipality to take over and operate all existing works in area for production and wholesale distr. of water to component municipalities, and to assume all outstanding

(*Continued on page 72*)

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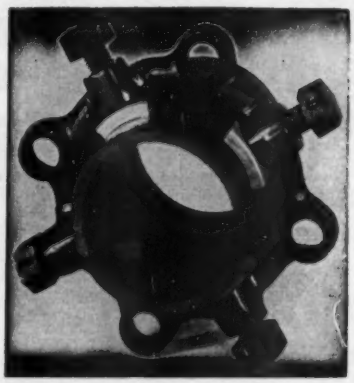

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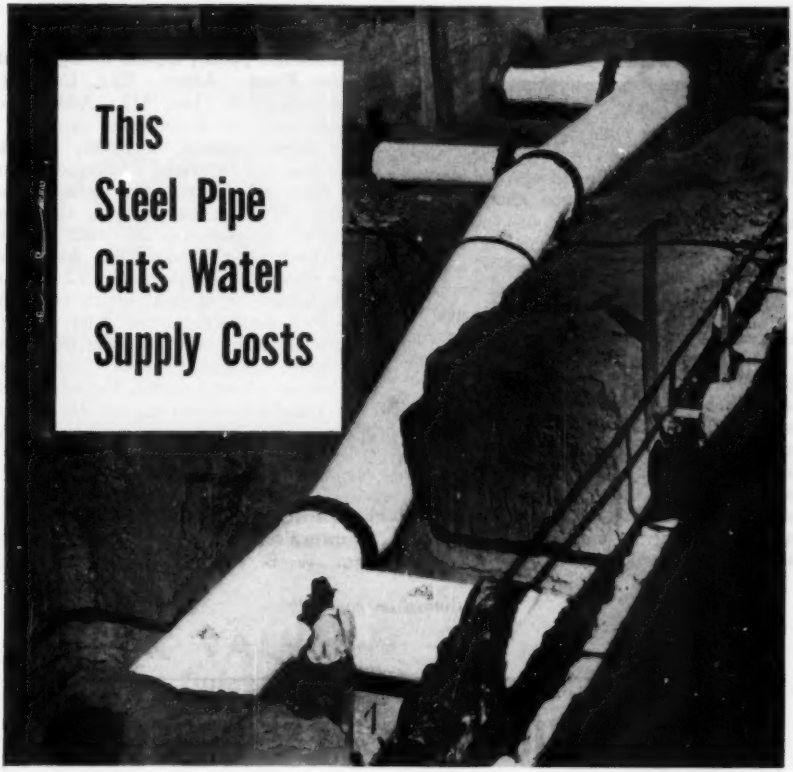

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Armco Steel Pipe also has a high strength-to-weight ratio that withstands internal or external pressures. It flexes with the load to guard against explosive bursting due to vibration or sudden overload.

You'll find Armco Pipe easy to handle and install. Jobs go fast and costs are low. Diameters of Armco Pipe range from 6 to 36 inches with wall thicknesses from $\frac{9}{64}$- to $\frac{1}{2}$-inch. Write for complete information. Armco Drainage & Metal Products, Inc., Welded Pipe Sales Division, 1284 Curtis Street, Middletown, Ohio. Subsidiary of Armco Steel Corporation. In Canada: write Guelph, Ontario.

ARMCO WELDED STEEL PIPE

ARMCO

Meets A.W.W.A. Specifications

(*Continued from page 70*)

debts for such works. Similarly, new municipality to establish comprehensive sewage and drainage system for entire area and assume all debts involved. Metropolitan council to have powers to fix wholesale rates for water to provide sufficient revenue to pay all capital and maintenance charges and establish reasonable reserves, any surplus to be applied to prepayment of debts or reduction or rebate of charges, and not to reduce taxation. At its discretion, council to have power to add special sewer service rates to water rates. Local councils to retain present powers to construct local mains, subject to approval of metropolitan council, which would also enforce uniform min. standards of maintenance and repair of local facilities. Local authorities to operate local distr. systems and fix and collect retail water rates. Operation of entire system by metropolitan council or appointed commission desirable but not essential in initial period.—*R. E. Thompson*

Scarborough [Ont.] Opens 10-mgd Water Works Plant. ANON. Eng. Cont. Rec. (Can.), **66**:1:120 (Jan. '53). Addn. placed in operation Dec. 1 increases capac. to 14 mgd. Plant consists of 3,000′, 48″ steel intake pipe in L. Ontario, reinforced concrete well below low-lift pumping station at base of bluff, 36″ discharge main in 450′ tunnel (6′ × 7′6″ in section), 24″ main to filter plant, feeders for Cl and alum, flash mixer, 3 flocculator and clarifier units (2-hr detention), 5 twin rapid sand filters (each half 16′ × 26′), 4-mil gal filtered-water reservoir, wash water pump taking suction from latter, and high-lift pumping station. Low-lift station houses 4 5-mgd pumps, 2 driven by elec. motors and 2 by diesel engines for auxiliary service. High-lift station similarly equipped. Brief construction details included.—*R. E. Thompson*

Radial-Cone Tank Is Important Unit in Stamford's [Ont.] Improved Water System. W. B. YOUNG. Munic. Util. (Can.),

(*Continued on page 74*)

WHY USE JOHNSON WELL SCREENS?

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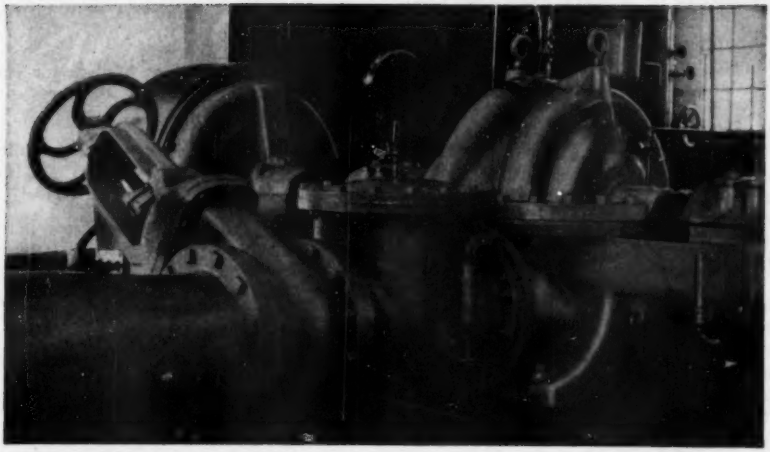

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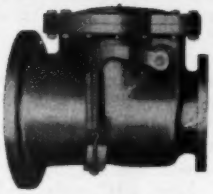

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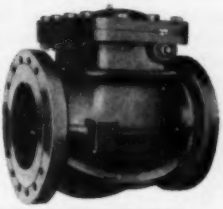
Rensselaer non-slamming check valves are made in sizes up to 30 by 30 inches. Standard check valves up to 60 inches for locations where slamming is not anticipated. High pressure valves up to 400 lbs. W.P. and 24". Ask for Catalog No. E. 106B



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SALES REPRESENTATIVES IN PRINCIPAL CITIES

(*Continued from page 72*)

90:12:13 (Dec. '52). Supply from 2 springs and from city of Niagara Falls, Ont. Latter's supply from Niagara R., purified in 12-mgd filter plant, which can be enlarged to 40 mgd; ample for both city and Stamford Twp., but distr. system inadequate. Only storage in Stamford 200,000-gal elevated tank erected in '13, and 8" mains no longer effective as feeders. As part of $1,250,000 improvement program, 500,000-gal radial-cone tank installed. Tank 67' diam., 100' from top of foundation to low-water line, supported on eight 42" tubular columns and 8'-diam. central riser. Water level range 25'. Ladder extends from grade up through column to platform immediately below tank bottom, access to roof being by ladder through 36"-diam. tube within tank to combination roof vent and manhole. Customary balcony thus eliminated, streamlining appearance. To limit max. angle to horizontal to 65 deg, sway rods run from base of column to top of third adjacent column, imparting hourglass effect when viewed from distance. —*R. E. Thompson*

New 24-mil gal Reservoir at Ottawa [Ont.]. C. T. HEENEY. Munic. Util. (Can.), **91**:7:23 (Jul. '53). Carlington Heights Res. approaching completion at cost of $1,200,000. Covered reinforced concrete structure, approx. 538' long, 404' wide, and 20' deep, max. water depth about 18'. Divided into 2 equal sections, interconnected by 36" and 18" valved crossovers. Earth cover 2' deep. Control bldg. houses 48" inlet-outlet piping, gate valves, deflector valves for regulating direction of flow to insure circulation, circulating pump, chlorinator, service pump, telemetering equip., etc. Feeder main, 13,800' of 42" and 4,300' of 48" pipe, has been completed.—*R. E. Thompson*

OTHER ARTICLES NOTED

Recent articles of interest, not abstracted, are listed below.

Classification of Surface Waters for Future Use—Panel Discussion. J. Boston Soc. Civ. Engrs., **40**:254 (Jul. '53).

Regulation of Flood Control Reservoirs in New England. E. F. CHILDS. J. Boston Soc. Civ. Engrs., **40**:189 (Jul. '53).

Gully Stabilization Structures Check Erosion in Western Iowa. G. M. BRUNE. Civ. Eng., **23**:590 (Sep. '53).

Soil Engineering. L. J. RITTER. Pub. Wks., p. 84 (Sep. '53).

New Water System Safeguards Historic Buildings. C. N. HAGAR. W.W. Eng., **106**: 786 (Sep. '53).

The Industrial Water Problems of Cities. ANON. Pub. Wks., p. 63 (Sep. '53).

How Electric Calculators Solve Water System Distribution Problems. G. W. REID & L. B. WOLFENSON. Pub. Wks., p. 78 (Oct. '53).

High-Rate Filtration of Water in Rapid Sand Filters. C. R. Cox. Wtr. & Sew. Wks., **100**:400 (Oct. '53).

Automatic Conditioning of Cooling Tower Water. J. W. SEGRAVES. Wtr. & Sew. Wks., **100**:406 (Oct. '53).

Secondary Contamination Held Down in Honolulu System. L. H. HERSCHLER. W.W. Eng., **106**:900 (Oct. '53).

Water Costs Drop With Pneumatic Chemical Handling. N. M. FULLER. Am. City, **68**: 11:86 (Nov. '53).

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THE MAIN LINE METER manufactured to Builders' traditional quality standards. Accuracy is within 2% over a wide range. Low loss-of-head. As easy to install as a valve or fitting. For Bulletin 380-K4, write Builders-Providence, Inc. (Division of B-I-F Industries, Inc.), 365 Harris Ave., Providence 1, R. I.

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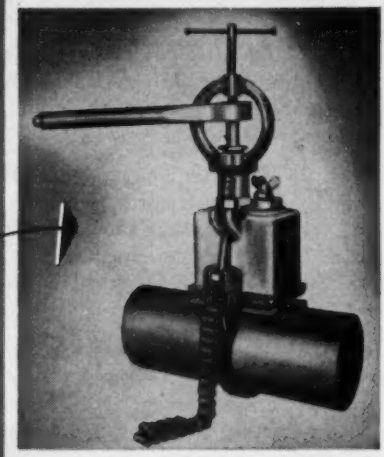

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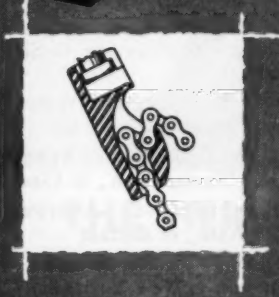

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Coming Meetings

(Continued from page 6)

Apr. 22–24—Arizona Section in Tucson. Secretary, M. V. Ellis, Supervisor, Sewage Treatment Plant, Phoenix, Ariz.

Apr. 23–24—Montana Section at Baxter Hotel, Bozeman. Secretary, A. W. Clarkson, Acting Chief, Water Section, Div. of Environmental Sanitation, State Board of Health, Helena, Mont.

May 25—Pacific Northwest Section luncheon meeting at Norselander Cafe, Seattle, Wash. Secretary, O. P. Newman, Exec. Vice-Pres., Boise Water Corp., Boise, Idaho.

Jun. 16–18—Pennsylvania Section at Americus Hotel, Allentown. Secretary, L. S. Morgan, Div. Engr., State Dept. of Health, Greensburg, Pa.

Jun. 22—New Jersey Section Summer Outing (inspection trip and luncheon) at Boonton. Secretary, C. B. Tygert, Box 178, Newark 1, N.J.

FALL SECTION MEETINGS

Sept. 9–10—New York, in Montauk, L.I.
Sept. 15–17—Michigan, in Muskegon
Sept. 20–22—Kentucky-Tennessee, in Nashville
Sept. 22–24—Ohio, in Dayton
Sept. 26–28—Missouri, in Jefferson City
Sept. 28–30—Wisconsin, in Green Bay
Oct. 13–15—Iowa, in Cedar Rapids
Oct. 17–20—Southwest, in El Paso, Tex.
Oct. 24–27—Alabama-Mississippi, in Birmingham
Oct. 26–29—California, in Long Beach
Oct. 27–29—Chesapeake, in Baltimore
Nov. 3–5—Virginia, in Richmond
Nov. 4–6—New Jersey, in Atlantic City
Nov. 7–10—Florida, in St. Petersburg
Nov. 8–9—West Virginia, in Huntington
Nov. 8–10—North Carolina

OTHER ORGANIZATIONS

Feb. 1–5—Corrosion Short Course, at Washington State College, Pullman, Wash. Sponsored by NACE and Div. of Industrial Services, Washington Inst. of Technology. Details from E. B. Parker, Director, Div. of Industrial Services, State College of Washington, Pullman, Wash.

Feb. 11–12—Ohio Water Clinic Conference, at Ohio State Univ., Columbus.

Mar. 10–12—Short Course for Water and Sewerage Personnel, at Louisiana State Univ., Baton Rouge. Details from John H. O'Neill, Director, Div. of Public Health Eng., Dept. of Health, Civil Courts Bldg., New Orleans 7, La.

Mar. 15–19—National Assn. of Corrosion Engineers, in Kansas City, Mo.

Apr. 21–23—Southern Industrial Wastes Conference, at Hotel Shamrock, Houston, Tex. Sponsored by Southern Assn. of Science & Industry and Texas Chemical Council.

May 4–6—American Public Power Assn., in Chicago

May 4–7—American Welding Society, in Buffalo, N.Y.

Jun. 13–18—American Society for Testing Materials, in Chicago

Jul. 25–31—Inter-American Conference of Sanitary Engineering, in Sao Paulo, Brazil.

Oct. 4–6—New England Water Works Assn., Poland Springs, Me.

Oct. 11–14—Federation of Sewage & Industrial Wastes Assn., in Cincinnati.

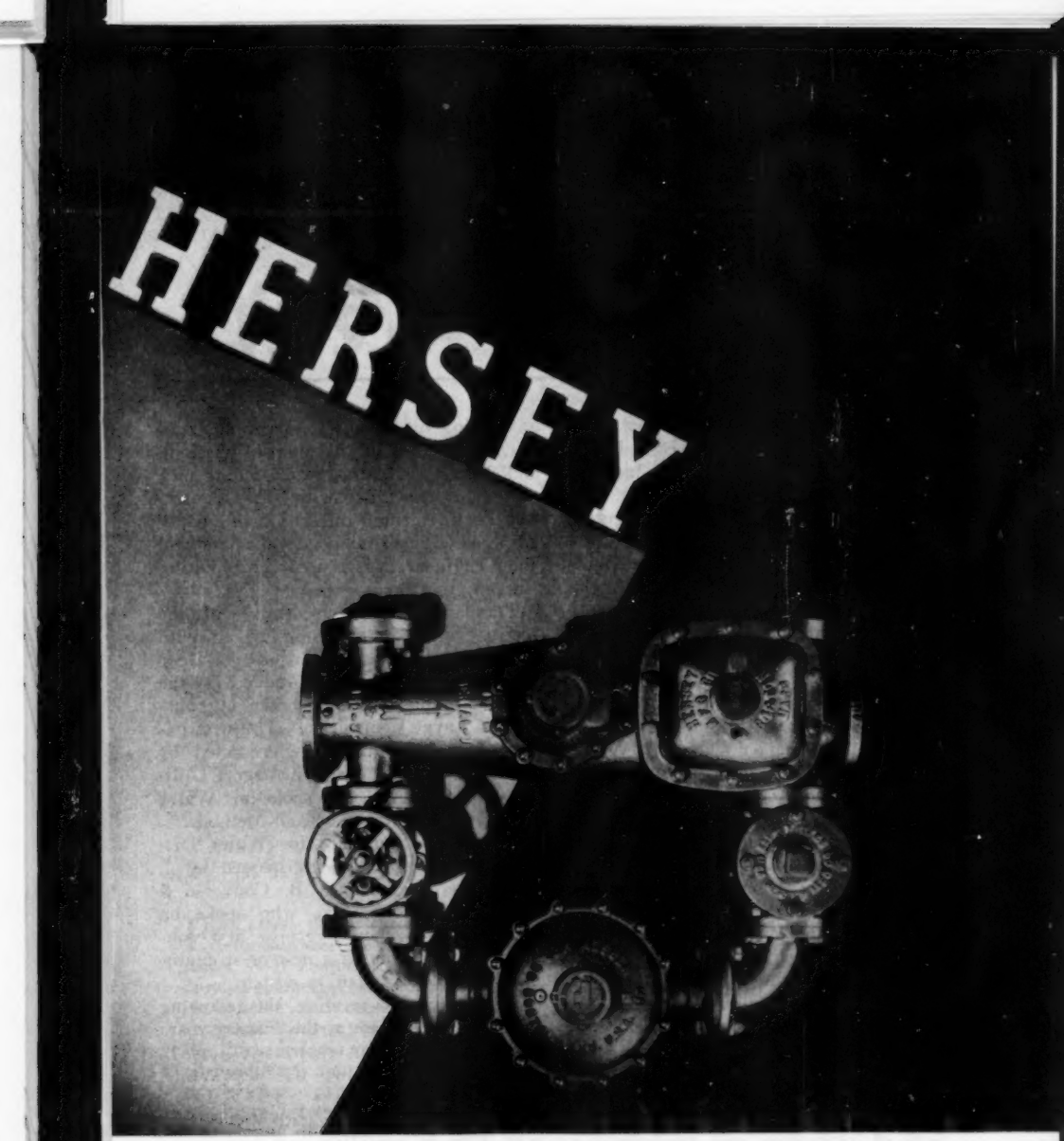
Oct. 11–15 (tentative)—American Public Health Assn., in Buffalo

Oct. 17–20—American Society of Civil Engineers, in New York City

Oct. 19–22—Pennsylvania Water Works Assn., in Atlantic City, N.J.

Nov. 17–19—Water Works Management Short Course, at Univ. of Illinois, Allerton Park, Ill.

Nov. 28–Dec. 3—American Society of Mechanical Engineers, in New York.



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Section Meetings

Alabama-Mississippi Section: The sixth annual meeting of the Alabama-Mississippi Section was held at Jackson, Miss., in the Heidleberg Hotel, Oct. 4–7, 1953. A total of 182 members and guests registered.

The registration desk was opened Sunday afternoon and the first feature of the meeting was a "Get Acquainted Party" held that evening. This social hour as well as the other delightful entertainment and refreshments enjoyed during the remainder of the meeting was a result of the work of the Club Room Entertainment Committee under Chairman W. O. Mullins and the Local Arrangements Committee under Chairman Hugh L. Burns.

The subject of a talk Monday morning by Vice-President Dale L. Maffitt was "Activities of the American Water Works Association." The last paper before lunch was presented by W. E. Hooper, general manager, Sheffield Light and Water Dept., who presented a factual paper entitled "Report on Fluoridation in Alabama and Mississippi to Date." His talk summed up the requirements of both state health departments, compared the various sources of fluoride, criticized the available feeders, and told of the various aspects of promoting and conducting a fluoridation program.

The afternoon session, presided over by Vice-Chairman W. H. H. Putnam, opened with a talk by John L. Snow, district engineer, Layne-Central Co., on "Pump Operation and Maintenance." "Billing Methods for Small Operations" was discussed by W. O. Haggard, Manager of Central Service Assn., Tupelo, Miss., which does the water, electric, and gas billing for a considerable number of towns and cities in Alabama, Mississippi, and Tennessee. Most water works men are deeply concerned with "Fire Protection Requirements," the subject of a paper by R. H. Tucker, associate manager and chief engineer, Mississippi State Rating Bureau, Jackson.

Tuesday morning's meeting, with the section chairman presiding, began with the showing of the motion picture "Deep Waters." This film was produced by the Layne organization and shown by courtesy of Layne-Central Co. The first paper of the morning was presented by Frank G. Crow, general manager, Utilities, Florence, Ala., who spoke on "Water Conservation—Necessity and Methods."

"Minimum Standards for Water Distribution Systems" was discussed by J. C. Clarke, engineer, J. B. Converse & Co., Montgomery, Ala., who spoke on matters which should receive first consideration in planning a new or strengthening an old distribution system.

At the business meeting, the following officers were elected for the ensuing year: W. H. H. Putnam, chairman; Jess L. Haley, vice-chairman; C. W. White, secretary-treasurer.

The afternoon session, with Vice-Chairman Putnam presiding, got under way with the showing of the motion picture "The Manufacture of Cast-Iron Pressure Pipe," shown by courtesy of the Cast Iron Pipe Research Assn. A panel discussion entitled "How Do You Do It" was then moderated by Jess L. Haley, superintendent, Clarksdale, Miss. The subjects and discussion leaders were: "Meter Reading," A. N. Fitzsimmons of Columbus, Miss.; "Meter Maintenance,"

(*Continued on page 80 P&R*)

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PIPE LINES don't "shrink" when interior surfaces are lined with Bitumastic 70-B Enamel . . . because this durable enamel prevents rust, corrosion, incrustation and tuberculation. With an inside diameter that *stays* the same, line capacity doesn't decrease. So there's no need, even after decades of service, to replace pumps with bigger ones that cost more to buy and operate.

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Section Meetings

(Continued from page 78 P&R)

Roy Stott of Greenwood, Miss.; "High Bill Complaints," Guy E. McAliley of Foley, Ala.; "Valve Maintenance," J. Earl Hamm of Sylacauga, Ala.; "Hydrant Maintenance," T. H. Collins of Birmingham, Ala.; and "Public Relations," Fred Scott Jr. of Leeds, Ala.

The annual banquet was enjoyed by many of the members and guests on the Heidleberg Roof. The announcement that entertainment would be provided instead of the usual afterdinner speech was met with a burst of applause. Afterwards dancing was enjoyed by many of the diners.

The last item on the program was an inspection trip Wednesday morning to the U.S. Engineer's Waterways Experiment Station at Clinton, Miss. This is a gigantic working model of the entire Mississippi River Basin and is used to study the basin-wide flood-control problems. A large group visited the Experiment Station and watched the great flood of 1937 reenacted in miniature.

The group agreed that an excellent, diversified program was planned and presented by the program committee, composed of Chairman Jess L. Haley, J. C. Clarke, and C. W. White. The 45 wives who attended the meeting had a variety of entertainment provided for them, much of the credit for which is due Mrs. Nina Burns, chairman of ladies' entertainment and wife of H. L. Burns, chairman of local arrangements.

C. W. WHITE
Secretary-Treasurer

Florida Section: The twenty-seventh annual conference of the Florida Section was held at the McAllister Hotel, Miami, on Oct. 11–13, 1953. The registration for the meeting totaled 287, including 86 ladies.

The official activities started with a "Get Acquainted Party" on Sunday night, a Club Room function that was well attended and enjoyed by all.

Technical sessions began Monday morning after an address of welcome by Mayor Chelsie J. Senerchia of Miami. Of particular interest to the local members was a talk on "Some General Problems of the Water Works Industry," by AWWA Secretary Harry E. Jordan. This was followed by two papers of international concern, one on "An Island Water Supply" by Geoffrey C. Stubbs and A. C. Langlois, director and deputy director, respectively, of public works, Nassau, Bahamas; and the other on "Projected Expansion of the Water Supply of Havana" by Manuel J. Puente and Jose Garcia-Montes Jr., consulting engineers from Havana, Cuba.

The Monday afternoon session included a paper on "Growth of Water Systems Due to Population Increases" by Charles E. Richheimer of Jacksonville, a paper titled "A County Commissioner Looks at His Water Problem and Its Solution" by R. Hosey Wick of Pinellas County, and a paper on "Hydrogen Sulfide Problems in Small Water Supplies" by Sidney W. Wells of Jacksonville.

A panel discussion on "Fluoridation" opened the Tuesday morning session. The moderator was A. P. Black of the Univ. of Florida, with Floyd DeCamp, Jacksonville, John V. Miner, Atlanta, and J. Ernest Edwards, dentist of Coral Gables, on the panel. A paper entitled "Is Your Safety Program All Wet?" by A. P. McIntosh of Tallahassee was followed by one on "The Desalting of Sea and Other Saline Waters" by C. E. Reid of the Univ. of Florida and F. A. Eidsness of Gainesville. The morning session concluded with a panel discussion on "Main Extension Policies," with David B. Lee of the State Board of Health acting as moderator. The other members of the panel included Stanley Sweeney of Pensacola, W. F. Savide Jr. of Naples, C. H. Helwick of Jacksonville, Max D. Holmes of Hallandale, and W. A. Glass of Miami.

The Tuesday afternoon session had papers on "Water Rates" by Harold D. Briley and Harry E. Wild of Daytona Beach, "Modern Iron Removal Practices"

(Continued on page 82 P&R)

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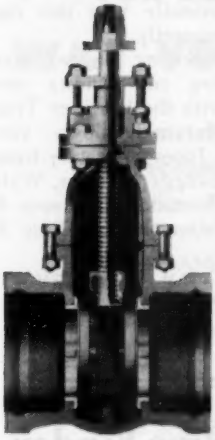

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Section Meetings

(Continued from page 80 P&R)

by Eskell Nordell of New York, "How to Keep 10,000 Bosses Happy" by Mrs. Lois J. Schulze of AWWA, and "Preview of New Miami Southwest Water Treatment Plant Trip" by C. F. Wertz, Miami. An unscheduled talk was also given on "So-called Water Conditioning Gadgets" by Rolf Eliassen of Massachusetts Inst. of Technology.

Because this meeting overlapped by one day the national FS&IWA meeting, all social functions were concluded Monday evening. The ladies were entertained with a luncheon and style show on Monday at the Algiers Hotel on Miami Beach. The annual banquet of the section was held that evening at the McAllister Hotel. The banquet was followed by a floor show after which the group retired to the ballroom for dancing. The Club Room activities during the three days of the conference were well received.

During the banquet it was announced that the 1954 Fuller Award nomination from the Florida Section would be S. Keith Keller of Clearwater. The presentation of the A. P. Black Achievement Cup was made by W. C. Gibson to D. W. Jones of North Miami who, because of having twice previously won this cup, will retain it permanently.

At the business meeting Tuesday afternoon the following new officers were elected to serve with the holdover Trustees: chairman, Marvin R. Boyce; vice-chairman, D. W. Jones; secretary-treasurer, Harvey T. Skaggs; director, Wylie W. Gillespie; and trustees, Clarence R. Henry, A. O. Patterson, and Ellis K. Phelps.

WILLIAM W. AULTMAN
Secretary-Treasurer

(Continued on page 84 P&R)

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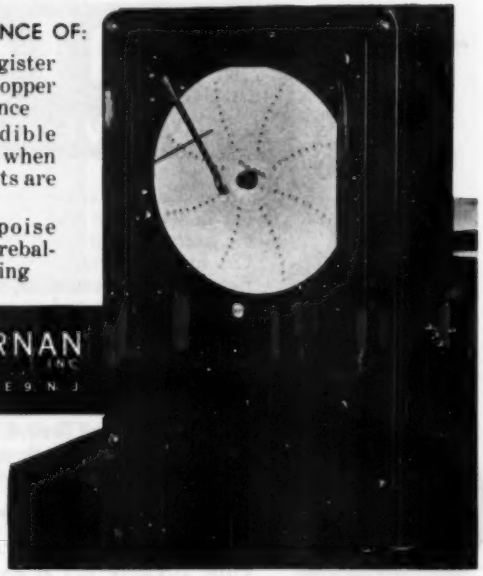

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Section Meetings

(Continued from page 82 P&R)

Cuban Section: The Cuban Section held its annual meeting at the Cuban Society of Engineers on Dec. 3–5, 1953. Due to the rather unsettled conditions, there was a question about the advisability of holding the meeting; however, it was decided to do so regardless of all obstacles.

For the past three months, the section has been collaborating with the Cuban Society of Engineers in holding a forum on the future source of supply for Havana, and discussions have been hot and heavy at all times, even reaching fever heat. Because of the forum, attendance was the lowest recorded in ten years, as a great many of the members were opposed to the holding of the meeting. Only 32 members registered, whereas in former years, an attendance of over 60 has been common.

The program was carried out to its entirety. Although disappointed because no representative of the national association could be present, those attending were glad to see a delegation from the Florida Section, headed by Chairman Marvin Boyce, a man well known and loved in Cuba. He was ably seconded by Caesar Wertz, whom many members of the Cuban Section look upon as a fellow member of their section, and whose good humor did much to make the meeting a success.

The section commemorated the centenary of Martí by placing a floral offering at his monument in Central Park, and the papers presented were extremely interesting.

As Havana suffered a very severe typhoid epidemic this past summer, there were several papers presented on this subject, and some very valuable data were obtained. Gustavo Bequer presented an extremely important paper on the minimum requirements for small water works.

(Continued on page 86 P&R)

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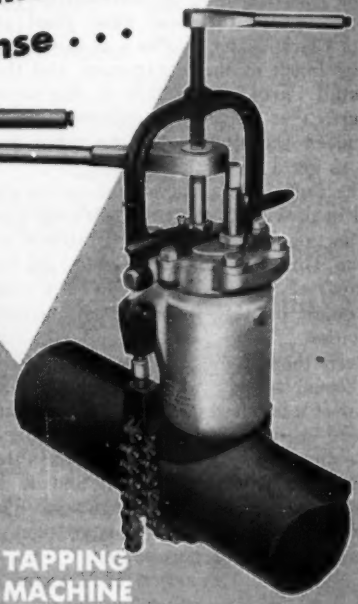

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Section Meetings

(Continued from page 84 P&R)

and he urged that the section establish a committee that would make up the regulations for water works in Cuba.

Instead of the Banquet, the section was invited by the "Acidos e Hipocloritos Company" that owns and operates a very fine chlorine plant at Sagua, to be their guest for lunch on Saturday. And so, at 6 A.M. (a very rugged hour indeed) about 40 members left in a specially chartered bus for a 200-mile trip to Sagua and Santa Clara, where, in addition to the chlorine plant, the new filter plant of Santa Clara Water Works was inspected.

The lunch at the Zaragozana and the Cocktail Party at the Bacardí Bar were features that are always enjoyed, and it is indeed regrettable that we were not able to get a larger turnout.

The Cuban newspapers were extremely kind in providing very fine publicity, and the section owes a debt of gratitude to Cucho Gutiérrez, of *El Mundo* and G. Parapar of *Avance*, who always are very thorough in the reporting of section activities.

Even though the meeting has passed, the forum is very much in the present, and over a hundred people, of whom about 60 are members of the section, attend these meetings. In the next few days the discussions will be resumed, and it is hoped that out of these discussions, the City of Havana will be able to plan a plentiful supply of pure water.

LAURENCE H. DANIEL
Secretary-Treasurer

Chesapeake Section: The Fifth Annual Meeting of the Chesapeake Section was held at the du Pont Hotel in Wilmington on Oct. 28–30th. Members and guests began to arrive on Wednesday, Oct. 28, on which evening the usual "Get Together," a social evening for all, was held in the Green Room of the du Pont. A total of 196 persons registered.

The next morning Chairman George L. Hall officially opened the session, introducing the Rev. William C. Munds for the invocation. Mayor August F. Wolz welcomed the members and guests to Wilmington, and the first paper was presented by Joseph Strohmeyer, water engineer of Baltimore, who spoke on the "Future Water Supply of Baltimore City." Equally enlightening discussion of this topic was offered by G. C. Requardt, Abel Wolman, and Harry B. Shaw.

A short panel discussion on "Water Supplies, Better or Worse" was led by Robert W. Haywood Jr. and included discussions by W. McLean Bingley, D. K. Harmeson, and Edwin R. Cotton.

E. S. Hopkins presented a paper entitled "Why Sanitation on Watersheds?" and concluded that the older, more conservative ideas on watershed sanitation have been modified. J. M. Jester discussed this idea and its applications. Clayton Hoff then presented an illustrated talk on "Watershed Control of Brandywine Creek."

Following lunch Robert J. McLeod spoke on "Utility Changes Required by Highway Programs," and this topic was actively discussed by R. C. Willson.

A panel on "New Water Works Equipment and Materials" followed, led by Bernard L. Werner. The first paper by J. C. Smith was a discussion of plastic pipe and was illustrated by slides showing local installations. David Wood offered a paper on instrumentation and controls, and Ray Orndorff presented more information on the application of plastic pipes in larger sizes. J. Farrell discussed experience with pipelines in the Washington Suburban Sanitary Dist. A paper on "Submersible Pumps for Municipal Application" was then presented by H. L. Frensdorf.

The Friday morning session opened with a paper on the "Occoquan Filter Plant," presented by E. H. Aldrich, who outlined some of the novel plants and their special design. A panel on "Special Filter Bottoms" followed, with Norman E. Jackson as moderator. Four types of filter bottoms were discussed, beginning with a description of the Leopold filter

(Continued on page 88 P&R)

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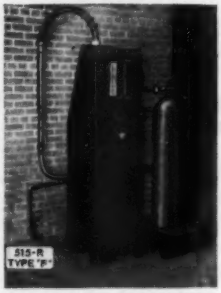

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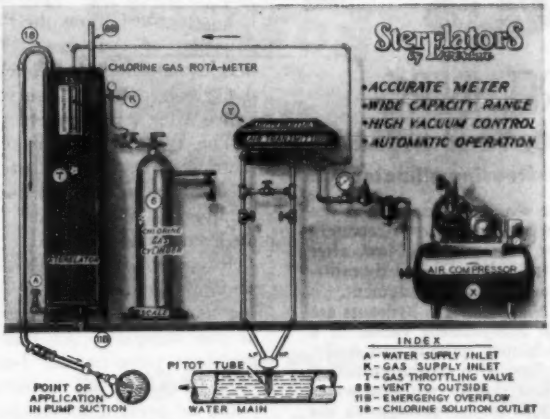

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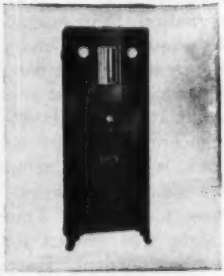

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Section Meetings

(*Continued from page 86 P&R*)

bottom by M. L. Stuppy. Richard Muller discussed the Wagner bottom, J. R. Hartley described the Wheeler bottom, and R. C. Roe discussed Carborundum plates.

The last paper was on the "New Wilmington Plant," presented by F. A. Marston. This new plant was also open for inspection to members and guests following the adjournment of the meeting on Friday noon.

On Thursday and Friday mornings the arrangements committee under Mr. and Mrs. Edward Showell's excellent leadership arranged for special trips for the ladies to the famous du Pont Winterthur Museum of Antiques. The ladies also had a complimentary luncheon on Thursday noon, and of course there was a dance after the banquet.

The Water and Sewage Works Manufacturers Assn. was host at a very congenial cocktail hour which preceded the banquet Thursday in the Ballroom of the du Pont Hotel.

Raymond Faust, executive assistant secretary of AWWA, attended the meeting as AWWA representative and spoke at the banquet. At this time two life members were named, Joseph Engle and Gus Requardt, but unfortunately neither could be present to receive their awards.

The Fuller award nomination went to Edwin A. Schmitt, the first Chesapeake Section Chairman, and, up to the recent date of his resignation, head engineer of the Washington Aqueduct in charge of all water supply treatment and construction. Mr. and Mrs. Schmitt just returned from a six weeks' trip to Europe and stopped at the meeting on their way to Chevy Chase, Md., where Mr. Schmitt is now engaged in consultation work.

At the business meeting on Thursday the following slate was elected for the forthcoming year: chairman, Harry B. Shaw; vice-chairman, John C. Tracy; director, David Auld; secretary-treasurer, C. J. Lauter; and, as trustees, R. W. Haywood Jr. and Bernard L. Werner.

C. J. LAUTER
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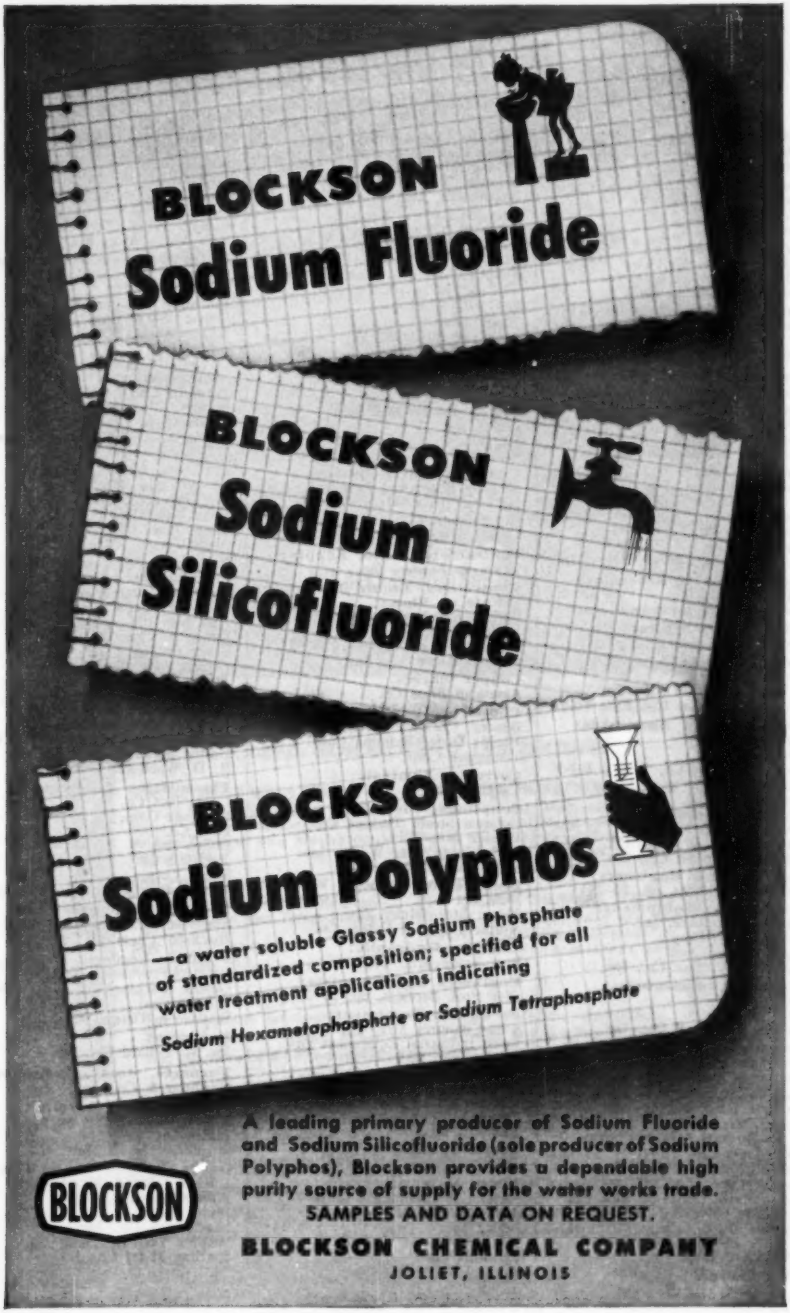
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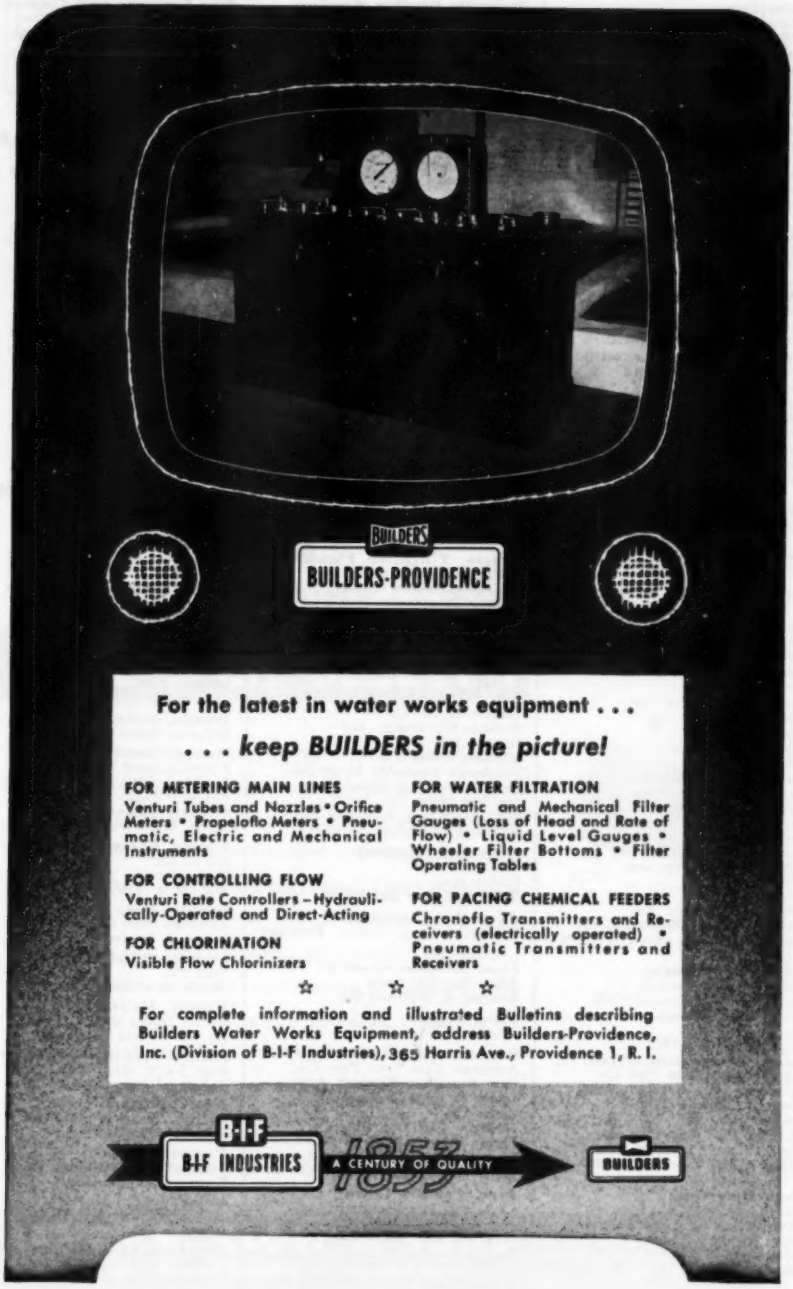

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Welsbach Corp., Ozone Processes Div.

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Hydraulic Development Corp.
Johns-Manville Corp.
Leadite Co., Inc.
Northrop & Co., Inc.

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Cast Iron Pipe Research Assn.
James B. Clow & Sons
Dresser Mfg. Div.
McWane Cast Iron Pipe Co.
Pacific States Cast Iron Pipe Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

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Dorr Co.
Infilco Inc.
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Permutit Co.

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W. S. Darley & Co.

Meter Boxes:
Ford Meter Box Co.
Pittsburgh Equitable Meter Div.

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Badger Meter Mfg. Co.
Dresser Mfg. Div.
Ford Meter Box Co.
Hays Mfg. Co.
Hersey Mfg. Co.
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Mueller Co.
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Pittsburgh Equitable Meter Div.
Smith-Blair, Inc.
Welsbach Corp., Kitson Valve Div.
Worthington-Gamon Meter Co.

Meter Reading and Record Books:
Badger Meter Mfg. Co.

Meter Testers:
Badger Meter Mfg. Co.
Ford Meter Box Co.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.

Meters, Domestic:
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Buffalo Meter Co.
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Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Well Machinery & Supply Co.
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Infilco Inc.
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Sparling Meter Co., Inc.

Meters, Industrial, Commercial:
Badger Meter Mfg. Co.
Buffalo Meter Co.
Builders-Providence, Inc.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Simplex Valve & Meter Co.
Sparling Meter Co., Inc.
Well Machinery & Supply Co.
Worthington-Gamon Meter Co.

Mixing Equipment:
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Infilco Inc.
Walker Process Equipment, Inc.

Ozonation Equipment:
Welsbach Corp., Ozone Processes Div.

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Johns-Manville Corp.
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American Brass Co.

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Cast Iron Pipe Research Assn.
James B. Clow & Sons
Crane Co.
McWane Cast Iron Pipe Co.
Pacific States Cast Iron Pipe Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Cement Lined:
Cast Iron Pipe Research Assn.
James B. Clow & Sons
McWane Cast Iron Pipe Co.
Pacific States Cast Iron Pipe Co.
Southern Pipe & Casing Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe Contings and Linings:
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Cast Iron Pipe Research Assn.
Centriline Corp.
Koppers Co., Inc.
Pipelife, Inc.
Reilly Tar & Chemical Corp.
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Pipe Jointing Materials; see Jointing Materials

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Jos. G. Pollard Co., Inc.

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Morse Bros. Mchy. Co.

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DeLaval Steam Turbine Co.
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Pumps, Turbine:
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Layne & Bowler, Inc.

Recorders, Gas Density, CO_2, NH_3, SO_2, etc.:
Permutit Co.
Wallace & Tiernan Co., Inc.

ENDURING PROTECTION

as traffic rumbles on!

Reinforce all hard-to-get-at pipe joints with

CLOW

MECHANICAL JOINT

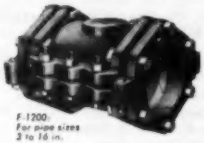
BELL SPLIT SLEEVES

F-1205: For pipe sizes 3 to 16 in.

Under the constant impact of ponderous, ever-increasing rail and vehicular traffic on our highways and railways, crossing underground water pipe lines require added protection. That is why foresight is so important. *Play it safe*—don't wait for a break. Install Clow Mechanical Joint Bell Split Sleeves as *original equipment* wherever pipe must pass under highway truck routes and railroad tracks. Specify them for marshlands and under water—everywhere pipe is not readily accessible in case of an emergency. Clow Mechanical Joint Split Sleeves are easy to install—no lead, jute, or calking.

Write for illustrated circular containing full particulars and other pertinent information.

★



F-1200: For pipe sizes 3 to 16 in.

F-1200 Clow Mechanical Joint Straight Split Sleeves are ideal for permanent repairs to pipe barrels. 12-in. and smaller sizes will repair any lengthwise break up to 8 in.; 14- and 16-in. sizes, to 17 in.

★

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201-299 North Talman Avenue • Chicago 80, Illinois

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James Jones Co.
Mueller Co.
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R. D. Wood Co.

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Darling Valve & Mfg. Co.
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Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

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Davis Mfg. Co.
Mueller Co.
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Wallace & Tiernan Co., Inc.
Welsbach Corp., Ozone Processes Div.

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Well Screens
Johnson, Edward E., Inc.

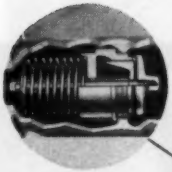
Wrenches, Ratchet:
Dresser Mfg. Div.

Zeolite; see Ion Exchange Materials

A complete Buyers' Guide to all water works products and services offered by AWWA Associate Members appears in the 1953 AWWA Directory.

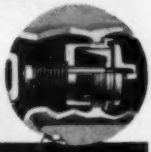
"Reduced Pressure"

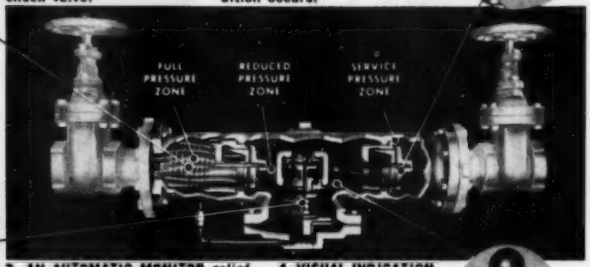
SOLVES CROSS CONNECTION PROBLEM

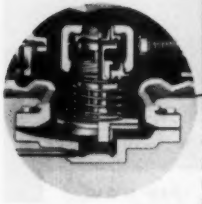


1. WATER PRESSURE from the main is reduced approximately 8 psi in the "reduced pressure" zone by this first spring loaded check valve.

2. THIS CHECK VALVE provides the "double check" protection and prevents drainage of the domestic system if a backflow condition occurs.







3. AN AUTOMATIC MONITOR relief valve in the "reduced pressure" zone is controlled by the supply pressure balanced against a spring and the zone pressure. This valve opens when unbalance occurs.

4. VISUAL INDICATION. Should any mechanical trouble occur, relief valve will discharge continuously to the atmosphere.

Makes Cross Connections Safe!

THE "REDUCED PRESSURE" PRINCIPLE used in Beeco Backflow Preventers employs a basic law of hydraulics which, briefly stated, is, "*fluid will not flow from a region of low pressure to a region of higher pressure.*"

By the use of two spring loaded check valves and the relief valve a zone of "reduced pressure" is produced to prevent back siphonage or backflow. The relief valve also acts as a monitor to give an instant visual indication of the improper operation of any vital part.

With this thoroughly tested and approved Beeco Backflow Preventer it is impossible for any pollution from cross connections to enter the pure water system. It offers the first positive protection for a water system because it prevents backflow and automatically indicates any mechanical trouble. Get the facts today; write for complete information.

BACKFLOW ENGINEERING & EQUIPMENT COMPANY
5725 ALCOA AVENUE, LOS ANGELES 58, CALIFORNIA

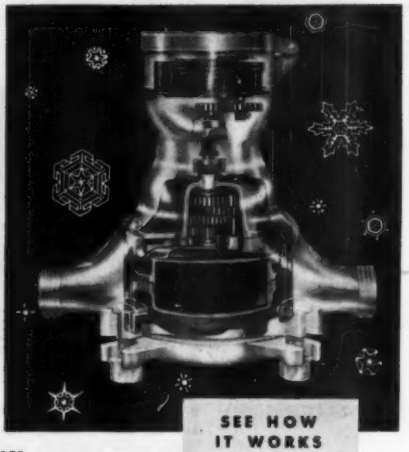
BEECO
It's Bonded

Reduced Pressure
BACKFLOW PREVENTER

AD NO. 2 OF SERIES. Ad No. 3 shows how to make "dual service" cross connections safe; copies available.

Q- What happens when a Rockwell-Empire Type 12 Meter FREEZES?

A-

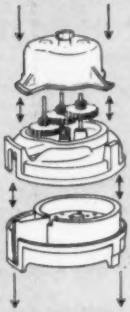


All interior parts SEPARATE to prevent damage!

The Empire Type 12 is the first meter to be fully frost protected internally. In this meter *alone*, the internal castings are jointed and held together without the use of screws or bolts. Thus, when the meter freezes and the frost bottom breaks, all the parts separate and are free to move with the expanding ice. There is no strain or distortion such as can occur in meters either having parts bolted together or with assemblies that are directly attached to the meter case.

Ask your Rockwell representative to demonstrate this and the many other money-saving, revenue-building features in the Empire Type 12 design, or write for bulletin W-802.

SEE HOW IT WORKS



Jointed castings separate to relieve against distortion.

THE EMPIRE TYPE 14

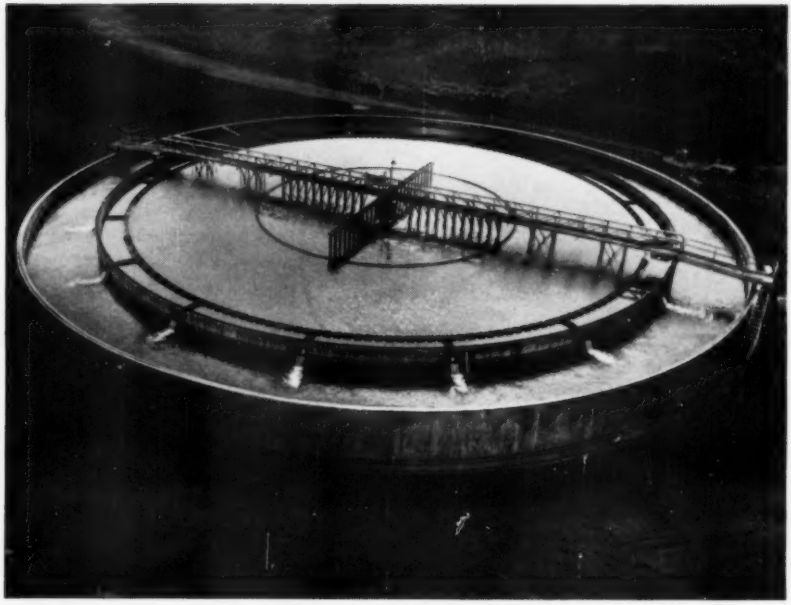
—for use in warm climates. An all-bronze meter having the superior performance of the piston type design and highly resistant to the effects of electrolytic action. Has fewer working parts than any other meter. Fully described in bulletin W-801.

The Symbol for Service, Quality and Performance in Water Meters

ROCKWELL MANUFACTURING COMPANY

PITTSBURGH 8, PA. Atlanta Boston Chicago Houston Los Angeles N. Kansas City New York Philadelphia Pittsburgh San Francisco Seattle Tulsa

In Canada: Peacock Brothers Limited



Located at Fibreboard Products, Inc., Antioch, Calif., this Clariflocculator treats 14 MGD of San Joaquin River water for process use. A 15' wide annular storage reservoir surrounds the 150' dia. Clariflocculator and a Dorrco VM Pump removes the dense underflow at minimum water loss.

No "Magic Formula" Approach Here...

Supplying 14 MGD of clear, process water for a West Coast Pulp Mill called for more than a "magic formula." Like all well-designed water treatment plants, it called for a detailed analysis of the problem. Raw water composition, rate of flow, results required, and local conditions were all studied before selecting the type of treatment to be used. The most efficient answer in this case was combination treatment with a Dorrco Clariflocculator.

There is no magic formula for every type of water treatment problem . . . no single equipment unit that will give ideal results under all conditions. For a brief picture of the complete Dorr equipment line for both conventional and high-rate treatment, write for Bulletin #9141, The Dorr Company, Stamford, Conn. In Canada: 26 St. Clair Avenue E , Toronto 5.

Clariflocculator is a trademark of The Dorr Company, Reg. U. S. Pat. off.

Every day nearly 8 billion gallons of water are treated by DORR equipment

Better tools TODAY to meet tomorrow's demand.

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LEADITE

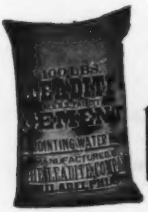
Jointed for . . . Permanence with LEADITE

Generally speaking, most Water Mains are buried beneath the Earth's surface, to be forgotten,—they are to a large extent, laid for permanency. Not only must the pipe itself be dependable and long lived,—but the joints also must be tight, flexible, and long lived,—else leaky joints are apt to cause the great expense of digging up well-paved streets, beautiful parks and estates, etc.

Thus the "jointing material" used for bell and spigot Water Mains MUST BE GOOD,—MUST BE DEPENDABLE,—and that is just why so many Engineers, Water Works Men and Contractors aim to PLAY ABSOLUTELY SAFE, by specifying and using LEADITE.

Time has proven that LEADITE not only makes a tight durable joint,—but that it improves with age.

The pioneer self-caulking material for c. i. pipe.
Tested and used for over 40 years.
Saves at least 75%



THE LEADITE COMPANY
Girard Trust Co. Bldg. Philadelphia, Pa.

No Caulking